Mutual Cultural Responsivity: Towards a Framework for Contemporary School Science

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In memory of my brother
Mark Daniel Ruddell
11.12.1961 – 04.09.2019

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Certificate of authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Charles Sturt University or any other educational institution, except where due acknowledgment is made in the thesis. Any contribution made to the research by colleagues with whom I have worked at Charles Sturt University or elsewhere during my candidature is fully acknowledged. I agree that this thesis be accessible for the purpose of study and research in accordance with the normal conditions established by the Executive Director, Library Services or nominee, for the care, loan and reproduction of theses.

Nicholas W. Ruddell

11 March 2019

Certification from supervisor

I, Associate Professor Lena Danaia, certify that the doctoral research entitled Mutual Cultural Responsivity: Towards a Framework for Contemporary Science is in a form ready for examination for the degree of Doctor of Philosophy.

Signed

Associate Professor Lena Dania

11 March 2019

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Ethical approval

Ethical approval for the research contained in this doctoral research was obtained from the Charles Sturt University Human Research Ethics Committee (Appendix A) and the State Education Research Applications Process (Appendix B).

Ethical considerations

The research has two areas that required ethical consideration. First, given that all students were under 18 years of age, all parents and guardians needed to be informed of the research. An opt-out approach was approved and employed to avoid the issue of low participation. Individual principal, teacher and parent/guardian and student Information letters (Appendices C–F) and consent forms (Appendices G–I) were written in language easily understood by the guardians/parents of school students. Participation was purely voluntary, and all participants were free to withdraw from the research at any time.

Burdens for students involved completing one pre- and post-occasion questionnaire (Appendices J–K), potentially engaging in group interviews (Appendix L) and being subject to group observation during the data collection period.

Second, the researcher was cognisant of the cultural sensitivities and language protocols of Indigenous Australians participating in the research. Regular guidance from the various Aboriginal Councils of Elders, Aboriginal Education Consultancy Groups and Charles Sturt University's Indigenous curriculum support staff was sought.

Abstract

Western educational systems have struggled to address the rising call for a science curriculum that includes Indigenous knowledge and perspectives. Furthermore, there is little research to show how to deliver a cross-cultural science curriculum in authentic and culturally competent ways. This doctoral research examines existing literature to establish what cross-cultural science education research has been conducted in the upper primary and lower secondary school context. A growing body of work suggests effective science delivery systems should engage with Indigenous communities, their epistemologies and their aspirations, however, the hegemony of Western science remains firmly in-place. Initially, this doctoral research investigated a cross-cultural pilot project that involved one Australian primary school, local Aboriginal Elders and the community. The program was mapped directly to the astronomy component of the National Science Curriculum. The results from the initial pilot program showed that educational outcomes can be strengthened when Indigenous knowledge is given the space to co-exist with Western science concepts.

In light of the pilot program and literature review, the research discusses and realigns the way in which we view the theoretical space that exists between Western and traditional Indigenous knowledge systems within school science. The middle-ground approach is defined as an entity in its own right, is a shared space containing legitimate perspectives, informed awareness of alternative cultures, and a vessel that provides the necessary knowledge that is relevant to the individual. To illustrate how educational projects might work in this contested third space, an Australian-based middle-school science program that blends both perspectives, and which is focused on astronomy, is described and investigated. The program was been implemented in 30 schools across New South Wales (NSW), Australia. Interview, questionnaire and observational data were collected from participants together with information posted on a project social

media site. These data were used to investigate the impact of the cross-cultural Sky Stories program on students, teachers and the wider community.

The findings indicate that the cross-cultural science program appears to have generated positive engagement for both Indigenous students and their non-Indigenous peers. Furthermore, results show that educators used the program to develop and maintain relationships with their local community. The research also suggests that Western educational systems can and should adopt knowledge diversity and cultural relevancy to promote a socially just learning space by offering multiple points of entry.

This research offers a new framework that positions where and how cross-cultural science education programs might work in the contested space between the two knowledge systems. The theory allows for the inclusion of Mutual Cultural Responsivity as each culture must exchange and respect knowledge and perspectives. Moreover, researchers need to develop programs that reach the higher levels of the Mutual Cultural Responsivity framework in order to move towards a contemporary understanding of school science for all Australians. The Cultural Competency matrix is extended from a capacity to a response model. The new framework provides the means by which one can assess and develop a response using three stages: Awareness, Becoming and Being. A framework that allows science educators to reflect, and operate, in the middle-ground between two equally valid knowledge systems. In doing so, new, contemporary methods of teaching and science learning can emerge.

Publications, submissions and presentations arising from doctoral research

Peer reviewed journal articles (in the order in which they appear in this doctoral research)

Paper 1: A review of literature of school science programs addressing indigenous perspectives: Developing and using criteria to assess research findings over a 10-year period (2006–2016) – *Asia Pacific Journal of Education*

Paper 2: Indigenous sky stories: reframing how we introduce primary school students to astronomy: a Type II case study of implementation – *The Australian Journal of Indigenous Education*

Paper 3: Working towards a contemporary understanding of mutual cultural responsivity in school science: an Australian perspective – *Cultural Studies in Science Education*

Paper 4: Enacting the middle-ground: An approach using Indigenous sky stories – *The Australian Journal of Indigenous Education*

Paper 5: Beyond the middle school science classroom: Using social media to connect the Indigenous Sky Stories community – *Teaching Science*

Presentations, interviews, podcasts, videos

2014	Interview released as Podcast CSU School of Teacher Education Bathurst	Sky Stories PhD research http://traffic.libsyn.com/tarabrabazon/Indigenous_sky_stories_with_Nicholas_Ruddell.mp3
2014	Video presentation CSU School of Teacher Education Bathurst	Sky Stories PhD research aims and associated teaching and learning materials
2014–2015	CSU Future Moves Middle-school astronomy workshops	Sky Stories PhD research/astronomy

2015	Presentation CSU Marra Marra Badhang exhibition Bathurst	Sky Stories PhD research/astronomy
2016	Radio interview 2MCE Bathurst	Sky Stories PhD research, general & Aboriginal astronomy
2014	Presentation Panel CS-Ued School of Teacher Education Bathurst	Sky Stories PhD research
2015	Aboriginal & Torres Strait Islander Alliance – Science & Technology, Engineering & Mathematics camp	Sky Stories PhD research/astronomy
2016	Presentation Panel Indigenous research summit Dubbo	Maori researcher practice in Indigenous Australian research
2018	Presentation – Indigenous research summit Wagga	Awareness, Becoming and Being – research in Indigenous science education

Statements from co-authors confirming the authorship contribution of the PhD candidate

Paper 1

As co-authors of the paper entitled *"A review of literature of school science programs addressing indigenous perspectives: Developing and using criteria to assess research findings over a 10-year period (2006–2016)"*, we confirm that Nicholas Ruddell has made the following contributions:

✔ Conceptualisation of the paper

✔ Review and interpretation of the literature

✔ Extraction and analysis of data for review

✔ Writing, editing, and revision of the manuscript

Furthermore, we agree to the inclusion of the paper in this doctoral research submitted for examination.

Nicholas W. Ruddell	11 March 2019
Lena Danaia	11 March 2019
David McKinnon	11 March 2019

Paper 2

As co-authors of the paper entitled *"*Indigenous sky stories: reframing how we introduce primary school students to astronomy: a type II case study of implementation. *The Australian Journal of Indigenous Education"*, we confirm that Nicholas Ruddell has made the following contributions:

✔Conceptualisation of the paper

✔ Review and interpretation of the literature

✔ Extraction and analysis of data for review

✔Writing, editing, and revision of the manuscript

Furthermore, we agree to the inclusion of the paper in this doctoral research submitted for examination.

Nicholas W. Ruddell	11 March 2019
Lena Danaia	11 March 2019
David McKinnon	11 March 2019

Paper 3

As co-authors of the paper entitled *"*Working towards a contemporary understanding of mutual cultural responsivity in school science: an Australian perspective*"*, we confirm that Nicholas Ruddell has made the following contributions:

✔ Conceptualisation of the paper

✔Review and interpretation of the literature

✔ Extraction and analysis of data for review

✔ Writing, editing, and revision of the manuscript

Furthermore, we agree to the inclusion of the paper in this doctoral research submitted for examination.

Nicholas W. Ruddell	11 March 2019
Lena Danaia	11 March 2019
David McKinnon	11 March 2019

Paper 4

As co-authors of the paper entitled *"*Enacting the middle-ground: An approach using Indigenous sky stories*"*, we confirm that Nicholas Ruddell has made the following contributions:

✔ Conceptualisation of the paper

✔ Review and interpretation of the literature

✔ Extraction and analysis of data for review

✔ Writing, editing, and revision of the manuscript

Furthermore, we agree to the inclusion of the paper in this doctoral research submitted for examination.

Nicholas W. Ruddell 11 March 2019

David McKinnon 11 March 2019

Paper 5

As co-authors of the paper entitled *"*Beyond the middle school science classroom: Using social media to connect the Indigenous Sky Stories community*"*, we confirm that Nicholas Ruddell has made the following contributions:

✔Conceptualisation of the paper

✔ Review and interpretation of the literature

✔ Extraction and analysis of data for review

✔ Writing, editing, and revision of the manuscript

Furthermore, we agree to the inclusion of the paper in this doctoral research submitted for examination.

Nicholas W. Ruddell	11 March 2019

Chapter 1: General introduction

Orientation to this doctoral research

This doctoral dissertation is presented as a PhD with Publications and is achieved through the submission and/or publication of five research papers, a sample of quantitative data results, and conclusion. Through interpretation of the existing research and consultation with supervisors, the five articles are structured both to stand alone as worthwhile contributions to the existing literature, and to contribute sequentially to the research aims. The structure of the papers is designed to loosely resemble that of a more traditional PhD dissertation. In accordance with the conventions of a Doctor of Philosophy, the papers will be accompanied by connective statements and a conclusion to link the separate papers into a single cohesive piece of research. The first paper, presented in the form of a literature review, explores the research base concerned with the employment of indigenous knowledge in school science education. Drawn from the research base published between 2006 and 2016, the review focuses on Australia, Canada, New Zealand and the United States of America exclusively.

Paper two uses a mixed-method case-study methodology to discuss a pilot cross-cultural science education program. The article describes some impacts and levels of engagement experienced by teachers, Aboriginal Education Officers and Year 5 and 6 students in one Australian school. Paper three in the series identifies and describes the trajectory of theoretical and methodological approaches that has influenced and provided the basis for this dissertation. The article also theorises a new framework that can act as a guide for practitioners in the field of cross-cultural research, teaching and learning. To illustrate how the theory may operate in the field, the development of the Sky Stories program is described in full.

The fourth paper unpacks and uses new “Middle-ground” and “Mutual Cultural Responsivity” theory to answer two research questions related to the overall progression, implementation and reactions to the Sky Stories program.

In-between the fourth and fifth paper is a Chapter that examines students’ patterns of responses from sample data collected from two participating Sky Stories schools.

The final paper examines the use of social media as a collaborative and engagement tool for participants in the Sky Stories program.

While the overall thesis employs consistent formatting, papers 1 and 3 are formatted to suit the requirements of their particular journal style guide. Paper 1 shows both the first and surname in the first usage. Paper 3 preferences US spelling. In both cases the papers use the US school level ‘Grade’ instead of ‘Year’. The reference list at the end of each paper also conforms to the requirements of the journal to which they have been submitted. In-addition, UN conventions have been adopted in relation to the use of ‘indigenous’. Indigenous’ is employed to show the localised Australian context while ‘indigenous’ is the general omnibus meaning.

As mentioned previously, the project has been designed to loosely resemble the structure of a traditional PhD dissertation. Table 1 shows how the proposed papers and chapters connect and how they form the overall narrative. While some overlap is unavoidable, the structure provides the narrative flow of a traditional monograph thesis. It should be noted that the structure will be supplemented with an overarching introduction and connectives between papers. The concluding chapter connects the separate papers and discussions into a single cohesive piece of research. That is to say, the conclusion restates and addresses the overarching question: *How can we align conventional scientific and Indigenous knowledge systems into a contemporary school science framework*? Finally, appendices are included to support the overall body of research.

Table 1: The connection between the proposed papers and a monograph PhD structure

Chapter/paper	Title	Chapter link
2/1	A review of literature of school science programs addressing indigenous perspectives: Developing and using criteria to assess research findings over a 10-year period (2006-2016)	Review of literature
3/2	Indigenous Sky Stories: reframing how we introduce primary school students to astronomy: A Type II case study of implementation	Introduction to theoretical frameworks/backgrounding
4/3	Working towards a contemporary understanding of mutual cultural responsivity in school science: An Australian perspective	Theoretical considerations/ research program description
5/4	Enacting the middle-ground: An approach using Indigenous sky stories	Theoretical considerations in-action, research program findings and discussion
6	Students' perceptions of science and experiences during the Sky Stories program	Quantitative data overview, results and findings
7/5	Beyond the middle school science classroom: Developing and implementing social media to connect the Indigenous Sky Stories community	Sky Stories participant engagement, results and findings
Conclusion	How can we align conventional scientific and Indigenous knowledge systems into a contemporary school science framework?	Interpretation, limitations, implications and conclusion

Context of the research

The context for this research was an innovative cross-cultural science education program that was introduced to upper primary and lower high schools across New South Wales over a four-year period. The program blends current Western science understandings with Indigenous Australian knowledge of astronomy in order to regain the interest of middle school (Year 5–8) students in school science. It involves students both exploring Indigenous Australian knowledge about the night sky and practicing curriculum-based investigative science. The program included professional development and support to enable teachers to deliver a variety of pedagogies that map to the Australian Science Curriculum content. Print and electronic learning materials, accompanied by content guides, were developed by curriculum specialists, the researcher and Wiradjuri Elders. These materials were made available to all participating schools. A 20-centimetre Dobsonian telescope, three eyepieces and a solar filter were given to all participating schools between 2013 and 2016. Community involvement was a major component of the program. It was expected that schools would engage with program-related learning materials and organise a cultural and night-sky observation event during one school term. Social media was employed to provide a hub for schools and the wider community to contribute and follow the progression of the Sky Stories program.

The Sky Stories program goals included providing opportunities for:

- Addressing the performance gap between Indigenous and non-Indigenous Australian students;
- Expanding teacher cultural content knowledge, competence and confidence;
- Localising 'stories' in school communities;
- Building an online community that engages with, and shares ideas about, teaching science and cultural perspectives to middle school students, and
- Working towards a framework for contemporary school science.

Background information and context sections are included in all five papers presented in this thesis. A full description of the Sky Stories program is provided in Chapter 4. The remaining four papers provide condensed versions describing similar information.

Research aims and objectives

The initial aim of the research was to investigate the impact the Sky Stories program had on Years 5–8 student knowledge outcomes and perceptions of science, and their teachers' perceptions of the science they teach. Due to the wide range of new practical and theoretical understandings that were uncovered during the program, the overall aims were modified to provide an investigation into what happened with all participants of the Sky Stories program and what the emerging theory was that underpinned it. Unchanged was the original objective which was to report on a program that supported the reclamation of Indigenous Australian knowledge while deepening the value and relevancy of science for teachers and students in the classroom. Table 2 shows the aims and objective in relation to the five papers contained within the thesis.

Table 2: Aims and objectives

Paper	Title	Aims & objective(s)
1	A review of literature of school science programs addressing indigenous perspectives: Developing and using criteria to assess research findings over a 10-year period (2006–2016)	Conduct a literature review targeting cross-cultural science education research over a 10-year period (2006–2016)
2	Indigenous sky stories: reframing how we introduce primary school students to astronomy: A type II case study of implementation	Investigate whether a fully supported teaching program, that includes locally sourced Indigenous knowledge and community, can inspire students to engage with the National Science Curriculum
3	Working towards a contemporary understanding of mutual cultural responsivity in school science: An Australian perspective	Examine and advance theory that supports the maintenance and/or development of inclusive school communities that engage with, and share ideas about, teaching science and cultural perspectives to middle-school students
4	Enacting the middle-ground: An approach using Indigenous sky stories	Theorise an approach where cross-cultural school science education research can occur in authentic and ethical ways
5	Beyond the middle school science classroom: Using social media to connect the Indigenous Sky Stories community	Explore how social media can engage school professionals, Indigenous and non-Indigenous students, their parents and the local community in school science.

Research questions

The overarching question that drives this doctoral research is:

- How can we align conventional scientific and Indigenous knowledge systems into a contemporary school science framework?

To fully explore the research question, the doctoral research investigated theoretical and practical aspects of cross-cultural science both within the context of the Sky Stories program, and externally by drawing on the literature base. While not always explicit, each of the five papers used the research question to underpin the narrative.

Paper 1 uses five explicit sub-questions to report on cross-cultural science programs across four Western countries, Australia, Canada, New Zealand and the United States of America:

1. Where is this research being conducted?
2. Who is the research targeting?
3. What are some of the characteristics of cross-cultural school science learning programs?
4. What research focus is being reported?
5. What impact results of the research being reported?

Paper 2 in the series attempts to investigate whether the Sky Stories program inspired Year 5 and 6 students to engage with the National Science Curriculum. The paper asks the sub-question:

1. What impact did the Indigenous Sky Stories program have on Year 5 and 6 science students?

Paper 3 investigates specific research approaches and describes the Sky Stories program in full in an attempt to answer two sub-questions:

1. What broad methodologies have been employed to investigate cross-cultural school science learning programs over the last 10 years?
2. What factors contribute to the success of cross-cultural school science learning programs?

Paper 4 uses two explicit sub-questions to explore a new theory for cross-cultural science education:

1. What experiences occurred when preparing and conducting the Sky Stories research program?

2. How did research participants react to the Sky Stories Sky Stories research program?

Paper 5 uses results from social media to show how middle-school communities collaborated and engaged in cross cultural science. Underpinning the paper was one sub-question:

1. How was social media used to show engagement during the Sky Stories Program?

Along with the main research question, the concluding chapter discusses the findings from the doctoral research by restating the overarching research question:

- How can we align conventional scientific and Indigenous knowledge systems into a contemporary school science framework?

Positioning of self in the research

I was born in Southland New Zealand in the 1960s. My maternal family were English immigrants who were decidedly agreeable to the popular notion that New Zealand was just like a little patch of England. In direct contrast to this my paternal Maori family come from Northland, New Zealand. Mum cooked bangers and mash. Dad cooked freshly caught mutton birds and flounder. Mum collected tea pots, Dad went 'bush' and collected Pounamu (Greenstone). Mum's family had roast turkey for Christmas. Dad's family had a Hāngi (a traditional method of cooking food using heated rocks buried in a pit) in the back yard.

Dad always wanted to move back up to his warmer, northern homeland but he could never talk Mum into the idea, 'too much of a culture shock' she would always say. As a concession, every second or third year we travelled the length of New Zealand to spend summer with my Uncles, Aunts and many cousins. It was here that we saw Dad in his real element. We feasted on freshly caught cod, oysters, mussels and pipis from the bountiful rivers, bays and seas of Northland. We visited the old sites in Pokatai where our family lived and saw gravestones in Parua Bay where our ancestors rested. It was always a lonely time for us kids when we returned home to the far south.

Except Dad, my immediate family all settled in Sydney from the late 1980s. I travelled back to New Zealand often and each time it became evident that the country was making a remarkable shift from colonial outpost to a proud Pacific nation. The re-birth of Maori Te Reo (the language) could be heard in the streets and on television. Artwork reflected a distinctive Maori feel. Mountain names were changed (e.g. Mount Cook reverted back to Aoraki), fishing rights were handed back to tribes some of who were, and still are, in the process of organising themselves for a final treaty settlement.

I enrolled in the Bachelor of Education (Primary) program in 2010. It was from that point I began to take an interest in the way Aboriginal students were being taught at schools. Later, reading for my honours thesis I became familiar with the two conflicting knowledge systems that promote two different ways of learning. The first was familiar; a euro-centric knowledge that is dominant in and outside of the school gates. The second, familiar to me during my childhood, is a pre-existing system, suppressed by years of racial intervention. My learned understandings are social, institutional and historical. Generated from critical understandings, the research journey experienced during the preparation of this dissertation has allowed me to understand and have deep empathy of what it means to 'be' from my own personal standpoint. I acknowledge that while I can empathise and operate with the utmost respect, I can never fully understand the past and present realities of Indigenous peoples of Australia.

The PhD research set out in this document takes on a dual journey for me. Through research, I propose to work towards the conceptualisation of a contemporary school science framework. Literature is drawn from the Australian and international research base. Data are collected from schools with a medium to high Aboriginal enrolment. The second part of my journey is to acknowledge and engage with my Maori heritage (Whakapapa). Through my paternal family, my homeland is Parua Bay on the east coast of Northland. My tribe (iwi) is Ngātiwai and I belong to the Pataua Marae. It is through this lens that I have conducted and present my PhD research. The journey has involved several interactions with many people and Peoples. Making these connections has increased my personal understanding of self. While there have been many, one personal understanding I bring from my Whakapapa is the process of *Utu* which means *balance* or *reciprocity*. In light of this, and with respect to the Wiradjuri on whose land this thesis was constructed, I now present my research in the remaining chapters for you to *Ngaabinyagi*, a Wiradjuri term meaning *research, examine, attempt, test, judge and evaluate*.

Chapter 2: Paper 1

Evidence of submission

Paper 1 – A review of literature of school science programs addressing indigenous perspectives: Developing and using criteria to assess research findings over a 10-year period (2006–2016). The paper was submitted to the *Asia Pacific Journal of Education* (APJE) on 21 November 2018 (Appendix M) and is currently under review.

Paper 1 – A review of literature of school science programs addressing Indigenous perspectives: Developing and using criteria to assess research findings over a 10-year period (2006–2016)

Nicholas Ruddell, Lena Danaia, David McKinnon

Abstract

This paper reviews cross-cultural science education research articles published between 2006 and 2016. Western educational systems have struggled to address the rising call for a science curriculum that includes indigenous knowledge in science. Our interest extends this notion in the first instance and in the second, advocates for a continuing improvement in the overall efficacy of research designed to investigate cross-cultural science education programs. Programs and practices that seek to extend our understanding of implementing effective research are analysed. More research in elementary school contexts, particularly in rural and remote locations is recommended. Increased funding for professional development, for both researchers and education staff, is seen as critical to the success of future studies. Including cognitive outcomes into the data collection mix would allow for a clearer picture of student learning. Future research in the field of Indigenous science education should also include culturally responsive methodologies that work in an agreed middle-ground space.

Key words: School Science - Indigenous Knowledge - Western Hegemony - Review - Culture

Introduction

This paper presents a review of published peer reviewed journal articles that discuss school-based science programs which include Indigenous knowledge or perspectives. The review identifies and summarises trends in research conducted in Australia, New Zealand, Canada and the United States (USA) between 2006 and 2016. Excepting the

USA, the nations chosen for this article have similar imperial histories; have a political system that actively promotes social policies to redress the gap between Indigenous and non-Indigenous education outcomes; and use English as a first language. While some similarities exist, the USA was included due to the large volume of research published in the area of Indigenous education. It is noted that the term indigenous is presented showing in the lower cap 'i' to mean indigenous peoples generally. Any discussion that specifically mentions an individual country's peoples, the capitalised 'Indigenous' is used (e.g., Indigenous Australian).

This work is important because no recent review has interrogated the efficacy, or highlighted the gaps, in cross-cultural science education research programs across multiple countries. In Guroux's (1992) seminal book *Border Crossings: Cultural workers and politics of education* and Stair's (1994) article *Cultural Broker*, powerful arguments for a re-thinking of the space contemporary science teachers work in were presented. Scholars (e.g., Aikenhead & Ogawa 2007; Nakata, 2007 & McKinley & Stewart, 2012) help provide frameworks for teachers to help students navigate the contentious border, or space, between Indigenous and Western knowledge systems in science. In the Western context, three particular countries and to some degree a fourth, have struggled to address the rising call for a science curriculum that includes Indigenous knowledge in science. Our interest extends this notion in the first instance and in the second, advocates for a continuing improvement in the overall efficacy of research designed to investigate cross-cultural science education programs. To that end, programs and practices that seek to extend our understanding of implementing effective, best practice cross-cultural pedagogies in the science classroom will be addressed in the discussion.

This review aims to answer six research questions:

1. What broad methodologies have been employed to investigate cross-cultural school science learning programs over the last 10 years?
2. Where is this research being conducted?
3. Who is the research targeting?
4. What are some of the characteristics of cross-cultural school science learning programs?
5. What research focus is being reported?
6. What impact results of the research being reported?

For over two decades, much has been written about the learning gap between Indigenous and non-Indigenous school science students (McKinley & Stewart; 2012; Tytler, 2007). Indeed, significant improvements in the delivery of school science has been accomplished in nations previously dominated by a colonial, hegemonic doctrine. Recognising the need for long term commitments, Governments and educational institutions have implemented programs that attempt to address the overall well-being of Indigenous peoples. For example, Australia's *Closing the Gap* initiative has attempted to address inequalities in education between Indigenous and non-Indigenous Australians for nearly a decade (Productivity Commission, 2018). Similarly, in Aotearoa, New Zealand the Maori Education Strategy*: Ka Hikitia – Accelerating Success 2013-2017* was implemented with the aim of improving the education system with which Maori students must interact.

Informed by culturally responsive priorities, building a science curriculum that effectively integrates elements from Indigenous and Western knowledge systems appears to be the appropriate model needed to improve learning opportunities for Indigenous school students (Aikenhead, 1996; Ryan, 2008). Reoccurring themes such as the unawareness of local language dialects (e.g., Aboriginal English) and the mismatch between home life and Western systems are acknowledged and provide the impetus to develop innovative and authentic teaching strategies for Indigenous children (Howard & Perry, 2005; Rennie, 2006). In the context of science literacy, engaging young Indigenous students with the curriculum by creating a bridge between the acquisition of language in their home-worlds, and developing the new language skills of the classroom is seen as crucial (Peers, 2006).

The question of how best to deliver science curriculum requirements in practical ways appears to remain elusive. This is despite the contemporary understandings, debate amongst academics, educators and legislators addressed above and is largely due to the epistemological tensions that dominate the middle-ground between Indigenous and Western knowledge systems. That is to say, for over two centuries, Western science culture has dominated school programs while Indigenous knowledge systems have either been dismissed out of hand, or at best assigned as an optional novelty. For over four decades, academic literature has both contributed to, and highlighted, the upwards trajectory of social change that largely agrees with the mandated inclusion of Indigenous ways of *knowing, being and doing* in science (Hackling, Peers & Prain, 2007; Harris, 1984; Harris, 1990; McKinley, Waiti & Bell, 2007; Snivley & Corsiglia, 2001). This 21st century middle-ground canon accepts that hard science can and should adopt knowledge diversity and cultural relevancy to promote a socially just learning space by offering multiple points of entry for all students (Ruddell, Danaia, McKinnon, 2016).

A similar social trajectory has been experienced in the types of research conducted in schools with high Indigenous enrolments. Previously viewed as a strictly Western set of paradigms, resistance in the form of anti-colonial, anti-hegemonic strategies now seek to offer research methodologies that align to the needs and protocols of specific Indigenous groups. Indigenised methodologies such as Australia's W*ays of knowing, Ways of Being*, *Ways of Doing* framework (Martin & Mirraboopa, 2003) and Kaupapa

Maori Research Methodology from Aotearoa New Zealand offer constructs drawn from historical and contemporary realities. Significant elements include language, adherence and acceptance of protocols and guidance from tribal Elders and significant members of a community (Bishop, 1992; Smith, 1999). Key to the research process is the emphasis on a "nothing about us, without us" approach that stresses cultural respect and reciprocity. Reclaiming both traditional and contemporary knowledge and ways of doing affords both Indigenous and non-Indigenous researchers with opportunities to collect and share data in an agreed third space, that is, a reconstituted 21st century middle-ground. Whether or not researchers choose to take advantage of these fresh ideas and approaches remains to be seen.

Method

This section described the search techniques undertaken to identify relevant literature and is confined to a 10-year period between the start of 2006 and the end of 2016. Two Boolean searches, shown in Table 1, were developed in collaboration with a specialist librarian. While these were developed as the primary search method, a list of keywords and phrases to allow additional searches were also developed and are also presented in Table 1. As noted earlier, Australia, Canada and New Zealand are included together due to the similarities of their British colonial histories and political frameworks. The USA was thought to be a valuable addition to this review due to the large volume of research of Indigenous education research.

Ten journal databases (*ERIC, Ebsco Host Education, ProQuest Education, Informit A, Informat Education, Taylor & Francis Online, Springer Link, Cambridge & Oxford Academic Journals*), were identified as being highly likely to contain references to relevant literature. In all cases, both the Boolean searches and keyword list were used to search for relevant literature. Including duplicates, the databases yielded 164 articles.

Table 1: Boolean formulae &, Keywords & phrases

Search Type	Search
Boolean 1	science OR STEM) AND (education OR (school* AND (primary OR secondary OR middle OR high))) AND (Australia* OR Canada* OR "New Zealand" OR Aotearoa) AND (Indigenous OR aborigin* OR Maori OR Inuit OR "Native Canadian" OR "First Nation*") AND ("Cross Cultural" OR Integrated OR Blended OR "Bi Cultural")
Boolean 2	(science OR STEM) AND (education OR (school* AND (primary OR secondary OR middle OR high))) AND (America OR United States* OR "USA" OR United States of America) AND (Indigenous OR Indian* OR "Native American" OR "First Nation*") AND ("Cross Cultural" OR Integrated OR Blended OR "Bi Cultural")
Keywords used	Science Education, Cross-Cultural, Indigenous peoples Knowledge, Australian Aboriginal, Canada first nation, New Zealand Maori, United States of America

Given its broad capabilities, Google Scholar was also used. Several attempts, using key search terms, were made to extract relevant articles. This strategy yielded a further 62 articles. The final phase of the literature search involved scanning the introductions, discussions and reference lists of the 226 papers to identify articles of research that had not been found using the previous steps. The most recent papers were searched initially. This strategy yielded 61 new articles. As noted earlier, searches were discontinued after 50 consecutive articles were found to be irrelevant. In the case of Google Scholar, searches were discontinued after 100 articles. The total yield from all phases of the searches was 287 articles. A master Excel Spreadsheet was used to house article titles, author(s) and abstracts. Each article was listed by publication date. An interrogation of the list led to 94 duplicates being removed leaving 193 articles for a second round of screening.

To improve topic relevancy, screening of these 193 articles was carried out by reading each abstract. If specific information related to Indigenous educational research was not present in the abstract a more detailed search was carried out by reading the overall document. A total of 83 papers were removed from the list as they were not focused on Indigenous perspectives in school science. This left 110 articles for review.

Categories for coding

A coding framework was developed to allow for the methodical extraction of data from these remaining 110 articles. Summarised data could then be used to answer the research questions. Initially, a broad reading of each abstract revealed potential categories for coding. Table 2 illustrates the 22 categories that were identified and which permitted the differentiation of research approaches and designs, duration, country, targeted participants and school grades. Community engagement, professional development and learning materials were also of interest and included in the list. These data were interrogated a final time to check that all categories had been coded and to ensure all relevant data were captured. This process resulted in an additional category related to the location of the research within a country where five location codes were used (urban, rural, regional, remote, mixed). No articles provided clear definitions of location based on the geographical standards used by each country. For example, the USA states that an urban area can be defined as 50,000 or more people living as a community and whatever is not considered urban is classified as rural (HRSA, 2017). The New Zealand statistical geographic standard and Statistics Canada, maintain an urban community is defined as 400 people or more or at least 200 address points per square kilometre. Consequently, location data are offered as a general guide only.

Coding data were extracted from a combination of the title, abstract, introduction, methods, results and summary sections. For articles that did not use this traditional structure, the whole document was read. In cases where data or content were non-existent or unclear, a *non-specified* code was assigned. For example, in cases that raised the need for *Types of community involvement* but no actual interactions involving community were outlined, a *not-specified* code was assigned for this variable. In another example, cases that discussed providing professional development but did not outline how or when it was offered, the *not-specified code* was recorded.

Table 2: Coding framework

Category	Codes for each category
Research Type	Theoretical or field research
Research focus	Cognitive, affective, cognitive & negative, none
Research impact	Positive, negative, positive & negative, none
Research Design	Qualitative, quantitative, mixed methods, not specified
Indigenised methodology	Yes or no
Research theme	String list - (e.g. culturally responsive; cross-cultural)
Research theory	String list - (e.g. constructivism; post-colonial)
Middle ground	Mentioned, mentioned & discussed, discussed at length, not mentioned
Data Collection	Survey, video, interview, work samples
Country	Australia, Canada, New Zealand, USA
Location	Metro, regional, rural, remote, mixed
Participants	Teachers, students, school professionals, community, Elders & significant others, researchers
Target population	Indigenous Students, non-Indigenous students, Indigenous & non-Indigenous students, not specified
Grades	Elementary school, High school, Middle school, not specified
Community Involvement	Yes, not specified
Types of community involvement	In-school single opportunity, in-school multiple opportunities, Out-school single opportunity, out-school multiple opportunities, not specified,
Elder involvement	Single opportunity, multiple opportunities, not specified
Professional development frequency	Single opportunity, multiple opportunities, not specified
Professional development delivery	Face to face, online, mixed, not specified
Professional development support	Support offered, not specified
Type of learning materials	Curriculum, physical, curriculum & physical, not specified
Delivery of learning materials	Paper-based, digital, mixed, not specified

In order to achieve a high degree of consistency and confidence in the coding process, the researcher attended sessions that involved comparing coding decisions of the same articles with two research team colleagues. A high level (> 95%) of inter-judge concordance was achieved during this process by offering five sets of randomly selected articles on three separate occasions. Once the results were deemed acceptable, the remaining 105 articles were completed by the first author.

Results

Interrogation of the 22 variables was conducted using the Statistical Package for the Social Sciences, SPSS v24. Using descriptive statistics, tables were generated for each Category to determine rates of occurrence across the articles. These data are expressed as counts and percentages in the results below. Where necessary, custom tables and bar graphs were also generated to compare data in relation to specifics such as country, location and targeted participants. An explanation of outcomes generated from the analysis of the 110 peer-reviewed articles are organised under the six research questions.

Question 1: What broad methodologies have been employed to investigate cross-cultural school science learning programs over the last ten years?

Of the 110 papers reviewed, 60 (54.5%) were theoretically based where only extant data were included while the remaining 50 (45.5%) were categorised as “field research”. Across the 110 papers, a broad series of factors are discussed concerning Indigenous education in science. The need to preserve or revitalise traditional Indigenous knowledge, the usefulness of various pedagogies, the performance of teachers and their abilities, or interest shown by students to engage with science content feature consistently throughout the research.

The 60 theoretical papers were further analysed for “types of theory” employed. While many different types of theory are reviewed in terms of having an influence on the aims of each article, 43 (72%) papers did not offer a specific theoretical approach. That is to say, only 17 (28%) papers offered a singular theory to underpin their research. A deeper interrogation of these data showed that no one theory dominated the overall body of research. For example, two papers used socio-cultural theory and one other employed a mix of socio-cultural and science education theory. Culturally-based education was used in two papers, with the remaining 12 papers employing an eclectic range of theories (e.g., cultural-historical activity, constructivism, plurism and post-colonial theories).

The overall themes that featured in discussions, within the 60 theoretical papers, was also thought to be of interest. It was found that a range of ideas were employed to frame the research. Of the 60 theoretical articles, eight (13.3%) discussed research aims in terms of advocating for *culturally responsive schooling or culturally responsive pedagogies*. Three (5%) use the term *culturally relevant* to describe the form of the science curriculum. Five (8.3%) articles discussed integrating Indigenous knowledge. That is to say, these papers discussed the inclusion, efficacy or measurement of Indigenous practices, culture and/or language in schools. It was noted that *decolonisation* as a main theme featured in only one (1.7%) paper. It was also found that of these 60 theoretical papers, 26 (43.3%) discussed themes related to *cross-cultural* and/or *border crossing* knowledge interactions. The remaining 17 (28.3%) covered a variety of related topics such as archaeoastronomy, education science policy, placed-based education and assessment data such as PISA results and means by which to improve Indigenous student performance.

Providing ways to navigate or alternatively circumnavigate the border between Indigenous and Western knowledge systems underpins a large proportion of the 60 articles. This theoretical border is expressed in two ways. First, as a *binary* is offered that requires a ‘crossing’ often back and forth. Second, a *middle-ground* or *alternative* space may be offered to position new understandings that use a blend of Indigenous and Western knowledges. A further interrogation into discussions concerning the theoretical *middle-ground* was undertaken. Table 3 shows that the *middle-ground* was discussed at length in 20 of the 60 articles. Results shown in Table 3 also suggest that of the 60 theoretical articles, the *middle-ground* term was present in a total of 37 (62%) of them. This appears to be important and is dealt with in the discussion.

Table 3: Presence of middle-ground discussions

	Counts	Percentages
Not mentioned	23	38%
Mentioned	11	18%
Mentioned and discussed	6	10%
Discussed at length	20	33%

Field research

The 50 field-research papers were also examined for examples of indigenised methodologies and frameworks. Given the cultural space in which the research was conducted, 42 (84%) employed a Western methodology and not an indigenised framework. That is to say, only eight (16 %) worked within an indigenised space. Closer interrogation of this group revealed three (6%) of the ethnographic articles in this category employed the New Zealand based *Kaupapa Maori Research* model while one (2%) used a combination of *Kaupapa Maori Research* and *Bronfenbrenner's* bio-ecological model. From Canada, three studies used Indigenous frameworks. Inspection of these data showed that two (4%) used *Inuit-Qaujimajatuqangit* (Inuit traditional knowledge) worldviews while one employed the *Ininiwi-kiskanitamowin* (a life-long strategy in science and mathematics) model. One (2%) article from Australia, employed the *Gamilaraay* (a South Eastern language group) worldview as a lens to frame the research. Given the focus of the research and acknowledgement of the need to address the Western hegemony in Indigenous Science education, the bulk of the research appears to be dominated my non-Indigenous paradigms.

The frequency of underlying themes discussed in the field-research papers were analysed. Results showed that of the 50 articles, six (12%) used *place-based* themes to underpin their research while *cultural relevance* was discussed in four (8%). *Culturally responsive* themes featured in three articles (6%) while another one article (2%) included a mix of *bi-cultural education* and *culturally responsive* themes. Yet another article (2%) employed a mix of *culturally responsive* and *culturally relevant* themes. Three (6%) articles were found to have themes unique to their particular countries. From New Zealand, *Maori science education* (Putaiao) appeared in two (4%) articles and from Canada, the theme *Inuuqatigiit* (curriculum from an Inuit perspective) featured in one (2%) article. The remaining 32 field-research articles featured a wide range of separate themes including professional development, sustained interest in science, and collaborative curriculum design.

Field-research articles that included discussions of, or mentioned, the theoretical *middle-ground* were analysed for frequency. The results show that the *middle-ground* was briefly mentioned in five articles (10%) whereas six (12%) mentioned and discussed the concept. Results also found that six (12%) other articles discussed the *middle-ground* at length. Of the 50 articles, 33 (66%) did not mention or discuss the concept at all.

An overall representation of the *middle-ground* data was thought to be of interest. Table 4 shows *middle-ground* frequency data extracted both theoretical and field-research articles. Results show the *middle-ground* concept was mentioned and discussed at length in 20 (18%) theoretical papers whereas only six (5%) discussions at length occurred within field-research papers. Overall, results from Table 4 appear to show the middle-ground theory was discussed significantly more theoretically than in the field. It was thought that studying alternative learning spaces in the field would be of interest to researchers.

Results indicate that of the 50 field-research articles, only three research design types were prevalent. It is also noted one paper (2%) did not specify a research design. Out of the 50 field-research articles, 27 (54%) used qualitative approaches, 17 (34%) employed mixed methods and ethnographic designs featured in five (10%) articles, while none featured quantitative methods.

Table 4: Presence or Absence of *middle-ground* discussion

	Theory articles		Field-research articles	
	N	**%**	**N**	**%**
Not mentioned	23	21%	33	30%
Mentioned	11	10%	5	5%
Mentioned and discussed	6	5%	6	5%
Discussed at length	20	18%	6	5%
Total	60	54%	50	45%

Table 5 presents frequency counts that show the types of data collection methods used. The table is divided into absent and present columns. The table indicates that interviews were most frequently used (80%). Table 5 also appears to show out of a possible 50 articles, 39 (78%) did not include student work samples. This method was the least popular method of the four prevalent methods. It is thought this finding merits further investigation but may be due to the fact that educative experiences may have involved listening to knowledge imparted by Elders and knowledge holders, and as a consequence no student products were produced.

Table 5: Presence of data collection methods

	Absent		Present	
	Count	**Row N %**	**Count**	**Row N %**
Video/Photo Images	32	64%	18	36%
Student Work Samples	39	78%	11	22%
Survey	35	70%	15	30%
Interview	10	20%	40	80%

Question 2: Where is this research being conducted?

Analyses of the 50 field-research articles show a breakdown of studies that were conducted within the four countries identified within this review (Australia, New Zealand, Canada and the USA). As anticipated, the USA produced the highest proportion of articles (32%) compared to the three other countries. Australia and New Zealand appear in the lower range with 10 (20%) and nine (18%) respectively. It is thought this warrants further investigation as comparatively, New Zealand has a small population (4.7 million) whereas Australia has a population of 25 million. Canada features in the middle range with 12 articles (24%). A total of three (6%) articles discussed research conducted in a combination of the four targeted countries or, one targeted country and another country, for example, Canada and Australia; Australia and Africa.

A closer interrogation of the data was possible following a frequency analysis of location data for each of the four targeted countries. Each article was coded to show whether research was conducted in urban, rural, regional, remote or, a mix of locations. Table 6 shows that three articles (30%) from Australia focused on, or conducted research in metropolitan areas while only one article (10%) discussed regional areas exclusively. Given the continent of Australia covers a vast landmass that is predominantly rural and remote, the lack of research in these areas warrants further study. This may be due to the difficulties and costs as a result of the extreme distances involved. Seven (44%) articles discussing USA field research were carried out in metropolitan areas and four (25%) were carried out regional areas. Excepting remote and rural locations, the multiple country variable shows exactly one (33%) article in each column across the range. Table 6 also shows how many studies were conducted in both urban and non-urban areas. New Zealand studies accounted for seven (78%) mixed-location articles while the Canadian studies included only three (25%).

Table 6: Frequency of location

	Metro		**Regional**		**Rural**		**Remote**		**Mixed**	
Country	Count	%	Count	%	Count	%	Count	%	Count	%
Australia	3	30%	1	10%	0	0%	1	10%	5	50%
New Zealand	0	0%	0	0%	2	22%	0	0%	7	78%
Canada	3	25%	3	25%	2	17%	1	8%	3	25%
USA	7	44%	4	25%	1	6%	0	0%	4	25%
Multiple	1	33%	1	33%	0	0%	0	0%	1	33%

Question 3: Who is the research targeting?

Figure 1 shows a breakdown of targeted study groups. It is noted here that each category of participant may not be exclusive to any one study. That is to say, combinations of two or more were noted in some studies. From a possible 50 articles, the most frequent group targeted by researchers for data collection overall was teachers followed by students. Interestingly, Elders or significant others included in data collection designs featured in only 10 (20%) articles. It is noted 7 (14%) articles included researchers in the data collection mix. This was due to the Action Research methodology employed. It was thought a closer inspection of the 28 (56%) articles that collected data from students would be of interest. A total of 27 (54%) articles collected data from Indigenous students exclusively while 19 (38%) articles discussed a "general student population". Only 6% of these articles collected data from non-Indigenous students. It noted here that one (2%) article did not identify which students they were targeting.

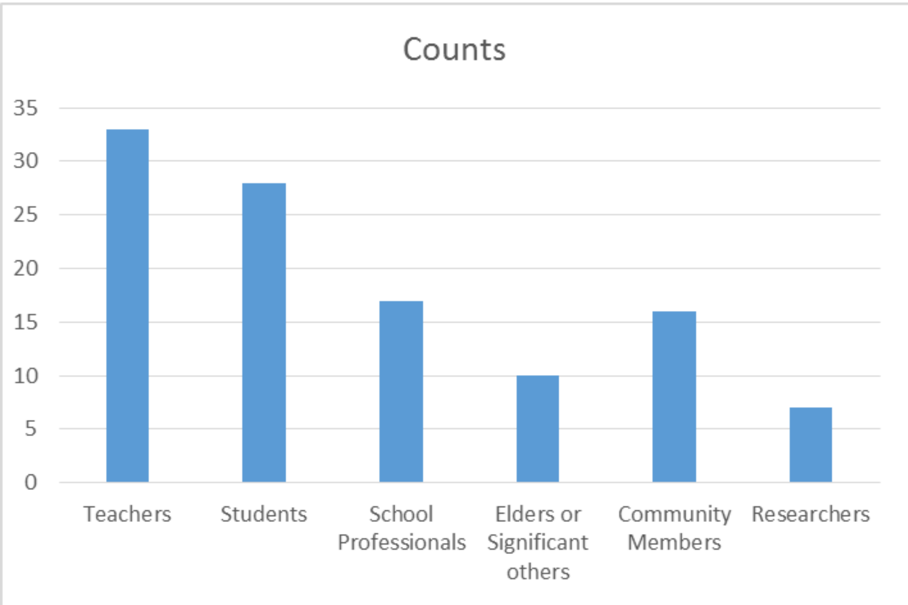

Figure 1: Targeted participants

Table 7 presents frequency counts and percentages that show the school grades targeted by researchers. Thirteen (26%) articles focussed on a mix of both primary and high schools. Six (12%) articles chose not to identify the grade they had investigated. In these cases, authors referred to the subject as ‘schools’ and focused on broader educative themes. It is also noted that only 9 (18%) of the 50 articles focused on elementary schools. The lack of research in the earlier years of science education involving Indigenous perspectives warrants further investigation.

Table 7: Target grades

	Count	Percentage
Primary/Elementary	9	18%
Secondary/High School	12	24%
Primary/Elementary & secondary/High School	13	26%
Middle School	10	20%
Not Specified	6	12%

Question 4: What are some of the characteristics of cross-cultural school science learning programs?

The integration of Indigenous knowledge or perspectives in science learning and teaching programs may benefit from the involvement of the local community, Elders or a combination of both. Analysis of these data show that of the 50 field studies, 24 (48%) articles mention researchers consulting or working with members of a local community and/or the Elders. This meant that over half of the reviewed field-research articles either do not clearly describe any interactions with the community or Elders, or chose not to include them at all.

Expressed in either in-school, or out of school opportunities for involvement, Table 8 shows the type of community participation reported in the 50 field-research papers. It can be seen that 19 (38%) of these reported consultation with six (12%) of the studies providing multiple opportunities for interactions out of school. Table 8 also shows that only five (10%) offered multiple in-school opportunities. Given the call for an increased presence of community representation in schools, this begs the question why is this not happening?

Table 8: Community involvement

	Count	Percentage
Not Specified	31	62%
In-School Single Opportunity	1	2%
In-School Multiple Opportunities	5	10%
Out of School Multiple Opportunities	6	12%
In & Out of School Opportunities	7	12%

The involvement of Indigenous Elders or designated significant others such as Aboriginal education officers was explored. Frequency data, presented in Table 9, shows 15 (30%) field-research articles reported multiple opportunities of involvement whereas 33 (66%) articles did not specify. The lack of involvement by local communities and/or Elders in science education research programs merits further investigation.

Table 9: Indigenous Elders or Designated Significant Other Involvement

	Count	Percentage
Not Specified	33	66%
Single Opportunity	2	4%
Multiple Opportunities	15	30%

Training and supporting teachers through professional development and learning materials were also thought to be important characteristics. Interrogation of the data shows that, in terms of frequency, 16 (32%) of the field-research articles reported the inclusion of multiple occasions of professional development for participants, while three (6%) articles provided a single opportunity. Overall, 31 (62%) articles did not specify any clear professional development opportunities for teachers or other school professionals. Closer inspection of the type of professional learning delivery and support provided beyond the initial training shows that 11(18%) articles discussed face-to-face learning. Only one (2%) article described an online offering and one (2%) other named a mixed-delivery method. A total of 17 (34%) articles described broadly the professional development support provided for participants. In terms of teacher or school reciprocity, further examination is offered in the discussion section of this review.

The presence of descriptions of learning materials used as an intervention or, as an investigation into the value of existing materials, was included in the coding of the articles. Of the 50 field-research articles, 20 (40%) contained no description of learning materials or did not outline clearly their relevance to the research. Seven (14%) articles described curriculum-based materials while only two (4%) used physical, hands-on activities. A total of 21 (42%) articles described using a mix of both curriculum and physical activities. Results also showed that of the seven (14%) articles that employed curriculum materials, three (6%) were delivered using digital tools while only one (2%) reported using paper-based products. In most cases 44 (88%), however, there was no description of how the programs were delivered.

Question 5: What research focus is being reported?

Table 10 shows the intended research focus extracted from the 50 field-research articles that were conducted. It can be seen that the majority of these articles were focussed on affective attributes 22 (44%). A further 15 (30%) articles focussed on both the cognitive and affective domains. That is to say, the most prevalent research focus investigated affective characteristics such as participant attitudes, behaviours, engagement, perceptions and social influences related to culturally integrated school science programs.

Table 10: Research focus

	Count	Percentage
None	10	20%
Cognitive	3	6%
Affective	22	44%
Cognitive and Affective	15	30%

Question 6: What are the impact results of the research being reported?

Table 11 shows the impact results of the research outcomes described in each of the 50 field-research articles. A total of 27 (54%) articles reported the achievement of the stated research goals or of favourable results related to an intervention, case study, hypothesis, or a combination of these while seven (14%) reported mixed results and 4 (8%) reported negative results.

Table 11: Research impact

	Count	Percentage
No change	12	24%
Positive	27	54%
Negative	4	8%
Positive and Negative	7	14%

Discussion

This paper has reviewed 110 articles related to Indigenous education in school science published between 2006 and 2016. The results show that, more than half of articles that fit with the aforementioned domain of integrated school science are theoretically orientated while the remaining articles presented and discussed data from field-research activities. Most of the research in this four-country review was conducted within the United States of America. An implication for future research in this domain would be to encourage more research in the Australian, New Zealand and Canadian elementary school contexts, particularly in rural and remote locations.

Drawing from earlier conceptual frameworks (e.g., Guroux's, 1992 *Border Crossing*, Stair's, 1994 *Cultural Broker*), the need to resolve the epistemological tensions between the hegemony of Western science and traditional Indigenous knowledge appears to be a consistent area of interest for scholars. It was found that two ideas were dominant across the 110 papers. The first of these is a binary construct that describes two knowledge systems with a 'border' between them that teachers and students must either "cross" or "travel over back and forth" to gain academic success. Providing ways to navigate (e.g., Aikenhead & Elliott, 2010) or alternatively circumnavigate (e.g., Aikenhead & Ogawa, 2007; McKinley, Brayboy & Castagno, 2008) this 'border' between Indigenous and Western knowledge systems underpins a significant portion of the articles. The second idea presents a middle-ground space, which is theorised as a meeting place in which Indigenous and non-Indigenous participants produce new, blended understandings of Indigenous and Western science knowledge systems (e.g., Gondewe & Longnecker, 2014; Reis & Hg-A-Fook, 2010). In Australia, Nakata (2007) describes this as a *cultural interface* and a legitimate meeting place between Western and Indigenous epistemologies. Constituted by multiple sets of relationships and realities, Nakata (2007) places the two systems alongside each other so that perceived differences can be identified, barriers dismantled and a common ground established. This seminal conceptualisation remains the benchmark description of the overlapping and highly contested knowledge domain.

Tensions between the hegemony of Western science teaching and the acquisition of traditional Indigenous ways of knowing also appears to be a consistent area of interest for scholars. For example, Brayboy and Castagno (2008) seek to disrupt the hegemony by suggesting that although Western science should help inform a curriculum design, Indigenous customs and practices should be at the forefront. At the other end of the spectrum Larkin, King & Kidman (2012) report on a study that adheres to Western-science investigative procedures that appear to adopt only a superficial treatment of Indigenous Australian knowledge. McKinley, et al. (2008) conclude that for Indigenous students, a dualistic approach that places Indigenous knowledge as a *legitimate* branch of science equal to Western science practices, ultimately produces the most favourable outcomes.

While mixed-method approaches were evident in the review (e.g., Stevenson 2014), the use of qualitative research designs dominated the field research. Data collection beyond interviewing, such as collecting student work samples, was not a priority for most of these educational research projects. Student work samples that were collected mainly consisted of drawings or maps to show perceptions (e.g., Gondwe & Longnecker, 2014; Laubach, Crofford & Marek, 2012). Indeed, researchers showed little interest students' cognitive abilities or understandings, choosing instead to report on mostly affective outcomes. While there were some instances of in-complete or missing technical qualities such as sample sizes and concrete results (e.g., Oscar & Anderson, 2009; Bang & Median, 2010), some very clear data collection designs (e.g., Miller & Roehrig, 2016; Higgens, 2014) show that the research base offers opportunities for replication. There were no instances of purely quantitative research designs evident. The gap identified here suggests there are opportunities to add to the research base by investigating cognitive outcomes using quantitative data collection methods.

As highlighted earlier in this article, the use of Indigenous methodologies and frameworks would appear to be critical in developing a mutual, cultural respect and reciprocity in research involving Indigenous and non-Indigenous stakeholders and the communities within which they live. With a focus on decolonization, Indigenous methodologies and frameworks question the legitimacy of Western notions of knowledge and research by advocating for a full recognition of values, systems and protocols congruent with the expectations of Indigenous peoples (Martin & Mirraboopa, 2003; Smith, 1999). Sutherland and Swayze (2013) employed the Canadian *Ininiwi-kiskanitamowin* (a life-long strategy in Science and mathematics) model to frame their research while Higgens (2014) and Lewthwaite and McMillan (2009) employ the Nunavut Territorial Government's conceptualisation of Inuit-Qaujimajatuqangit (Inuit traditional knowledge) worldviews. New Zealand's *Kaupapa Maori Research* is used, in part, as a lens to discuss a science education project for school communities (Wood & Lewthwaite, 2008). In Australia, Yunkaporta and McGinty (2009) use the *Gamilaraay* (a South Eastern language group) worldview to demonstrate how the research process and outcomes can co-exist alongside each other. The focus here is on the 'lessons, conflicts and stories' (Yunkaporta & McGinty, 2009, p. 62) learnt along the way. While they formed the minority in terms of the reviews, the examples discussed here demonstrate that decolonised, culturally responsive research methodologies and theoretical frameworks are available for academics to draw on in future research.

In this review, the presence of community (including Elders and significant others) working with researchers in a substantive or ongoing role was far less than expected. While the nature of the research may have precluded the need for consultations (e.g., Kidman, Abrams & McRae, 2011), researchers appear to bypass calls for respectful, authentic engagement before, during and after projects are implemented. Australian researchers (e.g., Oscar & Anderson, 2009) argue that effective cross-cultural curriculum design must be a product of collaboration between community knowledge repositories, schools and educators. Community members, who were the primary source of knowledge during the program, shared language, stories and ceremonial practices with fourth grade students, parents and staff for four consecutive weeks. This finding is consistent with Canadian research (e.g., Agbo, 2007), which argues for collaborative links between the school and the community that they serve. Similarly, Mack et al. (2012) highlighted the need for North American schools to engage with their communities to construct a hands-on, culturally relevant curriculum. Mack et al. (2012) offer a set of recommendations that serve as a starting point to strengthen the future development of effective cross-cultural pedagogies including: hands-on activities, locally sourced language, knowledge and practices informed by developing strong, collaborative relationships with local Indigenous communities.

Field-research articles showing detailed discussions involving professional development for teachers, school professionals or project related personnel involved in a research program were, at best, limited. Ensuring there is competency in pedagogical approaches and in Indigenous knowledge before and/or during studies take place, appears to have been mostly overlooked. A lack of funding to include professional development may contribute to this gap in research designs. Baynes (2015) calls for increased opportunities for professional development and participation in research to address attitudinal and pedagogical confidence in teaching Indigenous knowledge in science. Assuming educators are able to absorb and teach culturally specific interventions, initiatives and prescribed content, the lack of cultural competency credentials in researchers and education staff may also be a factor. More broadly, Bishop, Berryman, Wearmouth, Peter and Clapman (2012) report on a longitudinal study in New Zealand that showed a direct correlation between a change in teacher practice (augmented by professional training) and increased Maori student performance. Strong cases for providing adequate, long term professional learning opportunities for science educators (e.g., Peers, 2006; Perso, 2012; Tytler, 2008), appear to be warranted. In the context of the research base reviewed thus far, implications for future research could include funding for professional development to occur before interventions are implemented. In cases where a research article reports on current activities within the school community, the act of offering professional development to school professionals and ancillary staff would signify a willingness to engage with culturally responsive protocols that include reciprocity.

Conclusion

This review sought to answer six questions concerned with research on school science learning programs that discuss Western and Indigenous knowledge or perspectives. The favoured locations in terms of urban, rural, regional and remote areas across Australia, New Zealand, and Canada and, in a second round, the United States of America (USA) were examined together with who the research was targeting. The review also investigated the characteristics of school science programs and sought to determine the type and impact of the research. The articles included in this review were published between 2006 and 2016.

As expected, the USA dominated the research output. The data suggests that there is scope to increase research in Australian, New Zealand and Canadian elementary school contexts, particularly in rural and remote locations. In terms of offering optimum opportunities for all students, operating in a decolonised, culturally responsive, middle-ground space appears to offer a balanced approach to teaching and learning. However, increased funding for professional development for both researchers and education staff is seen as critical. Opportunities to add to the corpus of research also exist for investigating cognitive outcomes using methods that employ localised indigenised frameworks. More broadly, there is a need for educational organisations to initiate more Indigenous knowledge programs in school science and a need for increased research in this area.

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Connective statement

The first paper in the series introduced the cross-cultural science education research domain and provided a context for the overall dissertation. Titled *A review of literature of school science programs addressing Indigenous perspectives: Developing and using criteria to assess research findings over a 10-year period (2006–2016),* the paper highlighted the extent of the research base in the field of Indigenous science education.

The paper employed five research questions to frame a response. Literature that met specified criteria were drawn from Australia, Canada, New Zealand and the United States of America. An analysis of the essential elements that define cross-cultural, school science programs were identified and coded. While research criteria yielded theoretical research literature for discussion, the analysis mainly focused on research conducted in the field. That is to say, the majority of the analysis discussed field research that was carried out in the school teaching and learning environment.

Implications from the research included the need to provide more opportunities for teacher and associated staff training, particularly in the area of cultural competency and cultural responsivity. Moreover, providing more substantial roles for Elders and local community stakeholders was found to be an area that could be a valuable inclusion in future research.

In response to the findings from paper 1, Chapter 3 contains the second paper in the series. The paper discusses field research conducted in the science education domain. The aim of the paper is to investigate whether a fully supported teaching program, that includes locally sourced Indigenous knowledge and community, can inspire Year 5 and 6 students to engage with the National Science Curriculum. Titled *Indigenous Sky Stories: Reframing how we introduce primary school students to astronomy – a Type II* *case study of implementation,* the paper reports on a cross-cultural science unit taught to Year 5 and 6 students in one case-study school, during a school term (10 weeks).

Chapter 3: Paper 2

Evidence of submission

Paper 2 – Indigenous Sky Stories one case-study: Reframing how we introduce primary school students to astronomy Indigenous Sky Stories one case-study: Reframing how we introduce primary school students to astronomy. Paper 2 was published in the *Australian Journal of Indigenous Education* (AJIE) on 25 November 2016 (Appendix N). The article can be accessed on the AJIE website https://bit.ly/2xIsFmd

Reference

Ruddell, N., Danaia, L., & McKinnon, D. (2016). Indigenous sky stories: reframing how we introduce primary school students to astronomy: a type II case study of implementation. *Australian Journal of Indigenous Education*, *45*(2), 170–180.

Paper 2 – Indigenous Sky Stories one case-study: Reframing how we introduce primary school students to astronomy

Nicholas Ruddell, Lena Danaia, David McKinnon

Abstract

The Indigenous Sky Stories Program may have the potential to deliver significant and long-lasting changes to the way science is taught to Year 5 and 6 primary school students. The context for this article is informed by research that shows that educational outcomes can be strengthened when Indigenous knowledge is given the space to co-exist with the hegemony of current Western science concepts. This research presents a case study of one primary school involved in the Indigenous Sky Stories Program. It showcases how teachers and students worked in conjunction with their local community to implement the program. The results suggest that introducing cultural sky stories into the science program, engaged and primed Year 5 and 6 students to seek out additional sky stories and to investigate the astronomical content mapped to the National Science Curriculum. The involvement of Aboriginal elders and community enriched the experience for all involved. The integrated science program appears to generate positive engagement for both Indigenous students and their non-Indigenous peers. Additionally, the program provided a valuable template for teachers to emulate and which can act as a model for the requirement to include Indigenous perspectives in the new National Science Curriculum.

Keywords: middle-ground; astronomy education; Indigenous knowledge; middle school science; student engagement

Introduction

In this research, ‘science’ refers to a system of addressing a hypothesis, using appropriate, replicable methods to investigate, experiment, observe and describe phenomena (Aikenhead, 2001; McKinley, Brayboy & Castagno, 2008). Depending on the results, a hypothesis can be accepted as scientific theory or a truth about the world. 'School science' or 'Western science' refers to the hegemonic science methodology (as above) currently practised in Western education systems to date.

Since the late 20th century, science in general has become increasingly focused on accessing traditional Indigenous knowledge systems as part of a suite of solutions needed to deal with global environmental issues (IAEWG, 2012, International Council for Science, 2002). Recognising the need for Indigenous perspectives, researchers are producing studies that formally engage with Indigenous knowledge (e.g., Davis & Wagner 2003; Grech et al., 2014; Hind, 2015).

Australia has not been isolated from this fresh approach to science in general. In some cases, the nation's researchers and teachers have shown leadership by recognising and valuing Indigenous Knowledge systems and the relationship cultural ways of knowing has to science (IAEWG, 2012; PMSEIC, 2003). While tensions certainly exist between science knowledge systems and Indigenous knowledge systems (Aikenhead, 1996; Ryan, 2008), the groundwork has been laid to introduce programs that integrate the two systems to produce outcomes, which are both innovative and beneficial to the people they seek to serve.

Embedding cultural themes into the new National Science Curriculum (NSC) for schools is an approach adopted by the Australian Federal government. The NSC reflects an acknowledgement of Indigenous knowledge as a valuable resource with which to develop student competencies. This requires teachers to engage all students in science through the development of learning programs within which the students themselves want to be a part.

The need to act is driven by research (IAEWG, 2012; PMSEIC, 2003) that shows, to a large extent, Indigenous students find school science irrelevant and unrelated to their personal lives. This is reflected in the disparity between Indigenous and non-Indigenous engagement and learning outcomes across Australia, (IAEWG, 2012; MCEEYDA, 2010; PMSEIC, 2003). For example, the Trends in International Mathematics and Science Study (TIMSS) results from 2011 show that Australian Year 4 Indigenous students attained a lower mean score in science (458) compared with their non-Indigenous Australian counterparts (522) (Thomson et al., 2012). Furthermore, Indigenous students' mean score for science also fell below the international Intermediate benchmark set at 475. Students also responded to items about whether or not they liked learning science. Indigenous students scored significantly lower on this scale compared with their non-Indigenous counterparts. Similar results were reported for the scale measuring students' levels of confidence within school science where a significantly higher number of Indigenous students indicated that they were not confident with science (Thomson et al., 2012). These trends were also present in the secondary school results.

This disconnect with school science seems to continue beyond the compulsory years of schooling, where very few Indigenous students tend to pursue science in further study. In terms of science related careers for school leavers, statistics show that Indigenous students are less likely to find employment in science and technology related jobs compared to their non-Indigenous peers (2% compared with 7%), (IAEWG, 2012). Given these results, and the fact that the new NSC which incorporates Indigenous knowledge, is being implemented in Australian schools, it is timely to investigate the impact of a cross-cultural science program on both Indigenous and non-Indigenous students.

To date, few Australian studies have been conducted on the impact of implementing a science curriculum configured by integrating Indigenous knowledge with Western science concepts. Significant to the relevance of this research, we were unable to locate any Australian research that targets Year 5 and 6 primary school students interacting with cross-cultural science programs about astronomy. Given the importance the NSC places on ensuring Indigenous perspectives are integrated into school science programs, it is anticipated that investigating the impact of such programs would be of value.

The purpose of this research, therefore, is to investigate the impact of a school science program, *Indigenous Sky Stories* (ISS) that is focused on the astronomy content of the Years 5–6 NSC and which integrates Indigenous knowledge and science concepts, on students' perceptions and engagement of science. The pilot phase of this project involved 19 schools, identified as having high Indigenous student enrolments, drawn from the Western region of New South Wales. The current paper focuses on one primary school involved in the pilot program. In-depth accounts of what happened during the implementation of the program at this school are shared and student reactions reported. We also examine students' attendance patterns before and during their involvement in the project. Finally, we consider some of the implications for practice and further research.

Context for this study

The case-study school was selected from 19 Central West schools in New South Wales participating in a broader research program entitled Indigenous Sky Stories. The school was selected based on the following criteria: the school had to contain a mix of Indigenous and non-Indigenous students; the school, principal, teachers and students were amenable to being participants in this research; the school was located within a reasonable distance of our location; and, the school was actively participating in the ISS program.

The broader research program, Indigenous Sky Stories (ISS), was a pilot project funded in part, by Indigenous Student Services at Charles Sturt University (CSU), the NSW Department of Education and Communities (NSW DEC), and the Binocular and

Telescope Shop in Sydney. As part of the project, schools were provided with a 12-inch Dobsonian telescope, an iPad mini loaded with planetarium software to view the night sky, and a set of educational projects to address components of the new NSC. Face-to-face professional learning days, held at three Central West locations, briefed teachers and Aboriginal Education Officers on the project. Inquiry-based pedagogical approaches that are consistent with what is called for in the NSC were modelled to illustrate how the program could be implemented with their classes.

The program implemented several of the key recommendations made in previous national reports (Goodrum, Hackling & Rennie, 2001; Goodrum, Druhan & Abbs, 2011; IAEWG, 2012; Tytler, 2007). These included recommendations such as: targeting the middle years of schooling; employing investigative science; integrating local knowledge systems; and, implementing a professional learning program designed for the long-term development of teachers' pedagogical approaches and their scientific and mathematical content knowledge.

A mixed method, case-study of one pilot school participating in the ISS program is presented in this article. We share student reactions to cultural stories delivered by a local Aboriginal elder and, offer some insights into an ISS community event. Additionally, student attendance data is used to construct an argument supporting the notion that if students are engaged with a topic that interests them they will be motivated to attend school. Engagement with the ISS Project is also of interest in terms of Indigenous and non-Indigenous students' participation in the educational activities.

Theoretical framework

The theoretical basis upon which Indigenous science education should sit in a curriculum is influenced by the need to resolve the epistemological tensions between the hegemony of science and traditional Indigenous knowledge (Aikenhead & Ogawa, 2007; Hauser, Howlett, & Matthews, 2009; McKinley, Brayboy, & Castagno, 2008;

Ryan, 2008). A seminal article by Aikenhead (1996) informed the future debate by advocating an alternative way to help Indigenous students navigate the space between science and Indigenous knowledge systems.

Aikenhead provides a pathway for science teachers to reconceptualise themselves as cultural brokers tasked with acknowledging a student's personal perceptions and worldviews before introducing an alternative culture, i.e., a Western science methodology. Aikenhead (1996) maintains that this space exists in a cross-cultural border. The metaphor firmly sets the two knowledge systems in two separate places.

A decade later Nakata (2007) advanced the debate by configuring the *cultural interface* as a legitimate meeting place between Western and Indigenous epistemologies. Constituted by multiple sets of relationships and realities, Nakata (2007) places the two systems alongside each other so perceived differences can be identified, barriers dismantled and a common ground established. The seminal conceptualisation remains the benchmark description of the overlapping and highly contested knowledge domain.

The common or middle ground that allows a co-existence of Indigenous knowledge and science, albeit in the field of mathematics, appears to come from the findings of Warren and Devries (2010) who showed that Indigenous learning outcomes and engagement were improved when programs were contextualised towards their environment, language was modified and the local community was included. That is to say, the middle ground is the socially constructed cross-cultural space in which local Indigenous knowledge is informed but not dominated by, science systems (Aikenhead, 1996).

The literature also concerns itself with the integration of Indigenous knowledge into the science curriculum in terms of how much or how little should be employed to effect successful outcomes. For example, in New Zealand, McKinley and Stewart (2012) take the position that Maori students should be fully immersed into science practices using the Indigenous dialect, practices and knowledge. On the other end of the spectrum, Larkin, King and Kidman (2012) report on a study that adheres to science investigative procedures that adopt only a superficial treatment of Indigenous knowledge.

Understanding the home worlds of students and establishing strong community relationships appears to be critical for the success of culturally embedded curriculum design. This was shown by Mack et al. (2012) who found that student engagement could be strengthened by using hands-on, locally sourced language, knowledge and practices informed by developing strong, collaborative relationships with the Indigenous community.

Similarly, Bhathal (2008) showed that hands-on astronomy programs involving the community were a successful way to engage students with the high school science curriculum. Designed to help improve scientific literacy, a series of cross-cultural, astronomy activities engaged 15 lower secondary Aboriginal students. Consistent with research that examined the benefits of community involvement with schools (Harrison & Greenfield, 2011; Oscar & Anderson, 2009), the project's success was attributed, in part, to the attendance and participation of parents and the local community.

The tendency for academics to focus on the development of educational theory was challenged by Biermann and Townsend-Cross (2008) who articulate the need for further research into different Indigenised teaching strategies. They argue that one such alternative could be an Indigenous pedagogy based on the ideologies and belief systems of Indigenous Australians. While the teaching strategies employed to integrate Indigenous perspectives appeared sound for the sample of students presented in the study, providing content relevancy to Indigenous groups across the continent of Australia was thought to be problematic.

The theoretical and practical studies presented here appear to show that, in terms of student engagement and positive learning outcomes, local, socially constructed Indigenous knowledge involving hands-on activities with appropriately modified language that takes full advantage of existing science knowledge systems provided a workable middle ground between the current hegemony of science and traditional Indigenous ways of knowing. Providing this middle ground as part of an effective pedagogy appears to be impeded by the lack of professional training given to teachers.

Case-study school and data collection

In this case-study, the unit representing the "case" is a rural, co-educational primary school that accepted the invitation to participate in a broader ISS program and more specifically, the Year 5 and 6 students taught by their regular in-class teachers. In this article, we refer to the case study school as Ngaguwany-guwal Public school. We selected this name as it means 'all together' and we feel this is an appropriate reflection of the school community and is consistent with the project objectives. The Ngaguwany-guwal Public school enrolment comprises 49% Indigenous students and is attended by children from mostly low socio-economic family groups with an Index of Community Socio-Educational Advantage (ICSEA) value of 811 where 1000 is the national mean. The school's enrolment comprised 128 Indigenous students and 131 non- Indigenous students ranging from Kindergarten (Foundation) to Year 6. Specifically, this research involved one Year 6 and one Year 5/6 composite class. The class groups involved in this research comprised a similar representation to that of the school enrolment and were of mixed ability.

Ngaguwany-guwal Public school implemented the ISS program during the final school term (Term 4). The research team visited the school three times during the project implementation phase. Electronic communications were ongoing during the implementation of the program and have since continued.

During two of the school visits, interviews were conducted with four different groups of students about their participation in the project. Students, in groups of four, were asked about ISS related activities such as their interaction with telescopes, science investigations and whether they thought the program was worthwhile. Interviewees were selected by the classroom teachers and each group comprised two Indigenous students and two non-Indigenous students.

The recorded interviews were transcribed and conditioned for analysis using Leximancer; a software program designed for lexical analysis. The program uses Bayes statistical theorem to determine the probability that something exists, given prior probabilities, of different complimentary events (Kaplan & Garrick, 1981; Smith & Humphreys, 2006). That is to say, Leximancer progresses purely in examining the distances between words.

Activity and participation at the ISS community event was documented using anecdotal notes. Specifically, this involved taking notes and writing descriptions of events during the evening. At the night observation event, participants could manipulate two telescopes using an iPad loaded with a planetarium application called Stellarium. The event also included cultural dancing, story-telling and a barbecue. The night observation event was attended by the students and their parents, staff, and other members of the local community.

A digital camera was used to provide an indirect method to record student engagement by capturing images of student groups participating in classroom activities and of family groups using the telescopes and associated digital equipment. Photographic evidence was collected for presentation in two ways. A screen shot was extracted from a digital movie made by the classes involved in the project from Ngaguwany-guwal Public school. Images were captured during an impromptu daytime observation session and an organised night observation event using an iPad that has a digital camera fitted as standard equipment. The photographs chosen as evidence were downloaded onto a desktop computer. The images were manipulated using a cropping tool to re-size the photographs, no other editing was carried out.

Absence data for the school year were supplied by the school principal to reflect attendance before and during the implementation of the program. More specifically, the data identifies how many students were enrolled at the beginning of each term, their attendance prior to the introduction of the ISS project, and how many attended during the implementation of the project. The data were entered into an Excel spreadsheet for analysis. An analysis of absence data is undertaken by examining sets of divided-bar graphs that showed the weighted average number of absences for students in each of four school terms for the year the project was implemented.

Student reactions to the Indigenous Sky Stories program

Interviews were conducted with different groups of students on two separate occasions (a week apart) during the implementation of the program. On the first occasion, two student groups each containing four students were interviewed. The second occasion was conducted using the same student grouping arrangements of an Indigenous boy and girl and non-Indigenous boy and girl but comprising different students who were selected by their teacher. Students were asked about their involvement in, and perceptions of, the ISS program.

Figure 1: Lexical analysis of interviews conducted with Year 5 and Year 6 students

Figure 1 is a lexical analysis of four interviews conducted with a total of 16, Year 5 and Year 6 students. The diagram shows six themes. One, containing multiple concepts and identified as *Indigenous Sky Stories*, is very large and overlaps with another large theme identified as *Western science Concepts* also containing multiple concepts. Four smaller themes containing three or fewer concepts are identified as *Aboriginal*, *Active Participation*, *Investigation* and *Telescope*.

The overlapping themes in Figure 1 show that students appear to have embraced the cultural elements of the ISS program while making strong connections to Western science concepts of astronomy. In all cases, students were able to recount Sky Stories told to them during a special event organised earlier in the school term by the Aboriginal Education Officers. For example, S4, an Indigenous student, recounted a story he heard about the helical late rising of the star Sirius[1], which shines very brightly on the eastern horizon just after sunset during November and early December.

> The story about the fish is when the bright star was out in the sky, and they knew, the Aboriginals would know that there was fish in the river, because the fish usually would come, they would come at a certain time of the year, and that star, the star told them, what time it was, when to do it.

The statement demonstrates one of many succinct accounts of the fishing story. The story appeared to capture the imagination of the students and suggests that placed-based cultural stories may assist with engaging student interest.

Students also communicated their awareness of the differences between Aboriginal and Western culture. For example, S1, a non-Indigenous student, commented on the way Indigenous Australians view the night sky.

> It is different. It is kind of their culture and we have a different culture that we live in, it is a kind of different perspective than we are used to.

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[1] "Helical rising" means when the Sun is setting in the west, the object (the star) is rising in the east. In fact, this "star" has been identified as Sirius, the brightest star in the sky apart from our Sun.

The statement offered by S1 provides valuable insight into the educational outcomes achieved by the ISS Project. That is to say, cultural explanations concerning the night sky were presented as an alternative to the hegemonic Western science concepts usually taught and were viewed by this particular student as new, fresh information to consider.

The overlapping theme of *Active Participation* was apparent throughout the interview. For example, S3 recounted a request by the Aboriginal storyteller to prepare a physical backdrop to the stories so student learners could experience both oral and visual representations of the stories.

> Our class and the other classes painted the Aboriginal flag, the fish, the Christmas star and the bright star, we all had goes at painting them.

Once the paintings were completed, students participated in the storytelling process. An example is provided by S6, an Indigenous student, who succinctly described the storytelling event.

> About 15 people [were] holding [the pictures]. We painted big A4 papers on the Moon, stars and fish and all that, and this traditional old, nice lady come in and told stories about it and half the hall sat down and we all enjoyed it.

Figure 2: Screen shot from sky story-telling event movie

Figure 2 shows an extract from a movie that recorded a cultural story-telling event at Ngaguwany-guwal Public school. It can be seen that students are using the Aboriginal flag and artworks relating to cultural stories concerning the morning star, the Southern Cross, and the Christmas star as a backdrop for the story-teller.

The value of using a local Indigenous storyteller was a point of conversation during the interviews. For example, S5, an Indigenous student, attempted to explain why she could relate to the stories told at the Sky Stories event.

> Probably would have been just as exciting but not as personal if she was not a local. We heard that she is around.

S5, referring to a respected member of the local Indigenous community, appears to reflect that because she and her peers knew the storyteller, a personal connection was able to take place.

Figure 2 also shows *Investigation* as a theme that connects with *Indigenous Sky Stories*. During the interview students said that after learning about celestial objects such as the Moon in science class, coupled with listening to various sky stories, they attempted their own observations. For example, S7 recounted that he looked for the helical rising of the star Sirius.

> She [the story teller] said around November and December you look up in the sky, you see the Christmas star, I looked up and tried to find it.

S8 gave an account of what she saw when observing the Moon.

> "... I was at my grandmothers. I looked up into the sky and saw a face, a smiley face on the Moon."

The observations by S7 and S8 appear to demonstrate an interest in finding celestial objects in the night sky in their own time. No causal attribution of the ISS program is offered here however.

Figure 1 also shows *telescope* as a satellite theme. At the time of the interview, students had not taken part in any formal observations using the donated telescope. Nonetheless, two weeks earlier the first author helped deliver and set up the telescope at Ngaguwany-guwal Public school, resulting in an impromptu observation session involving the Sun using a Solar Filter. When asked to recount what he had looked at during the day, S9 offered the following comment.

> We have been looking through the telescope out there [the school yard]. We looked at the Sun, it had black dots [sunspots].

The comment gives a clear account of what S9 observed through the Sun filtered telescope. Comments by students not shown here included some exasperation that they had not yet used the telescope since the impromptu event held three weeks earlier.

Finally, an unexpected and wholly surprising outcome of the interview occurred when an Indigenous student was motivated to share a short sky story. The student had been discussing the ISS program with his father while they were travelling.

> My dad told me on the way back from Walgett, because the Moon was red, my Dad said that "Remember, when an Aboriginal person dies it goes red" and that is what I believe.

This sharing of personal sky stories was not an isolated event during the ISS program. It appears that in some cases, the ISS program served as a catalyst for students to set aside their usually reserved manner and offer valuable insights into stories passed down to them by significant others.

Results from the Leximancer analysis coupled with the interview showed that students made strong connections between Indigenous Sky Stories and Western science concepts. Students discussed their involvement with the ISS program and particularly the Sky Stories event held in their school hall. Indeed, the cultural stories appeared to intrigue the students and clearly motivated some of them to search for stars and the Moon in the night sky. Students felt that listening to a local storyteller enhanced their appreciation of the event because it was more personal. Finally, an unexpected outcome of the program was the re-telling of personal Sky Stories by some of the students as told to them by their parents.

Indigenous Sky Stories Community Event

Included in the ISS program was the expectation that each participating school would organise an early evening event that would involve their community. The ISS community event at Ngaguwany-guwal Public school began with observations of the Sun followed by a barbecue, cultural dancing, watching a school-produced sky story movie and culminated in observations of phenomena in the night sky. Anecdotal records of what happened during the evening were recorded on a writing pad and later transcribed electronically. We note that the data are anecdotal but feel it important to share as it helps illustrate student participation and engagement generated by the community event.

One of two telescopes used at the community event was fitted with a Sun filter allowing observers to view the Sun safely. Students were astonished to find several sunspots in different positions on the Sun's surface. An Indigenous student (S1) took a particular interest in this phenomenon and was prompted to ask what the Sun spots were and then followed a set task that involved tracking the Sunspots by an adult student helper. Observations of S1's interest were recorded in the anecdotal notes.

> It was suggested that he [S1] could record where they [Sunspots] are located using a picture of the Sun as well as log the time he saw them.

The anecdotal notes also report that S1 counted the Sunspots and logged the time that he observed them. S1 was observed asking the time from adults and writing the results down diligently. After a period of time, S1 observed the Sunspots again and claimed that they had moved. S1 recorded the new positions and noted down the time with the help of passing adults. Interestingly, S1 appears to have developed a process methodology for collecting data based on scientific observation and time. The surprising aspect of this exchange was that S1 was known by his teachers to be semiliterate and had difficulties telling the time (statement by teacher). Despite this, S1 completed this task, albeit in an unorthodox manner.

> The student seems to have problems writing things down. He recorded all of this information on his hand and arm, we helped him write it out on paper.

It was also recorded that the adult student helper recognised the difficulties S1 was experiencing before helping him transcribe the information onto paper. Once the information was on the paper, S1 went and asked his teacher if he could present his findings to the assembled night observation participants but she did not appear to be interested at that point in time. It was noted later, however, that when the teacher had time, she looked at S1's work and was suitably impressed.

It was documented in the anecdotal records that the ISS community event participants were encouraged to take photographs of the Moon and Venus by placing their cameras onto the eyepiece of the telescope. Students tended to "monopolise" the telescope in order to get the "perfect" shot.

A further example of student engagement documented in the anecdotal notes was when students were asked to form pairs and were challenged with the task of locating Venus using the planetarium software on their iPads (see Figure 3). Once found, students had to move the telescope to the same location, and focus it on Venus.

Figure 3: Community event photo collage

On the top left side of Figure 3 a student from Ngaguwany-guwal Public school can be seen posing with his Sunspot observation data with an amplified image of his work shown to his right. The top right side of the collage shows Indigenous and non-Indigenous students sharing the telescope to observe the Moon in the daytime. The image on the bottom left shows students, their parents and members of the community watching a sky stories movie made by the students at Ngaguwany-guwal Public school. The bottom right image shows two students working together to locate Venus using the donated iPad and telescope.

Absence data

An analysis of absence data for Kindergarten to Year 6 students was conducted to identify patterns in students' absences before and during ISS project. Comparisons were made across the four terms of the average weighted absence for all students, the non-Indigenous students, and the Indigenous students.

In an attempt to understand any patterns in the absence data an analysis of the absence data was undertaken by inspection of the two divided-bar graphs presented in Figures 4 and 5. These show the weighted mean number of absences for all students in three groups in each of the four school terms: Grades Kindergarten to Year 4 combined, Year 5 and Year 6. The number of students in each grade remained largely the same from term to term. Figure 4 shows absence data for non-Indigenous Kindergarten to Year 4 combined, compared with Year 5 and Year 6, for each of four school terms (T1, T2, T3 and T4) during the year of program implementation. Figure 5 presents the same absence data for Indigenous students.

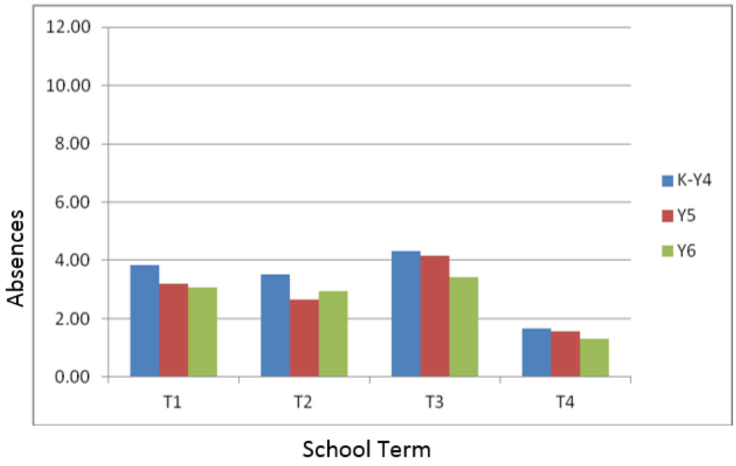

Figure 4: Mean weighted absences for non-Indigenous students K-4 combined, compared with Year 5 and Year 6, for each school term.

Figure 4 shows the average weighted absences for non-Indigenous students in Kindergarten to Year 4 combined (blue), compared with Year 5 (red) and Year 6 (green), for each of four school terms, T1, T2, T3 and T4. The data in Figure 4 shows a greater number of student absences in Term 3. It may be noted that Term 4 has a very low weighted mean average absence rate compared with the other three school terms.

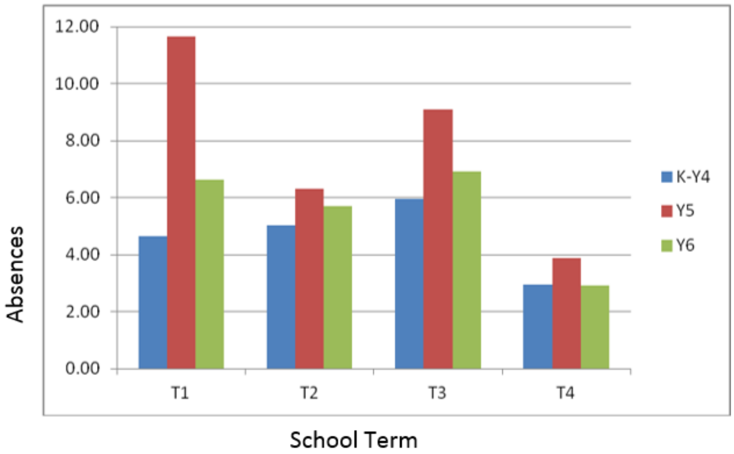

Figure 5: Mean weighted student absences for Indigenous students K-4 combined, compared with Year 5 and Year 6, for each school term.

Figure 5 shows the average weighted absences for Indigenous students in Kindergarten to Year 4 combined, compared with Year 5 and Year 6, for each of four school terms, T1, T2, T3 and T4. Figure 5 appears to show that overall, Year 5 Indigenous students have a higher average rate of absence. When compared with the data in Figure 5, it appears that in all cases, Indigenous students have a higher average rate of absences than non-Indigenous students. There is also a greater variation of absences in each of the four terms for the Indigenous students compared with the non-Indigenous students. Again, it can be seen that Term 4 has the lowest weighted mean average absence rate compared with the other three school terms.

The pattern that emerged from these data broadly suggests that Indigenous students overall, have a higher mean absence rate and a greater variation of absences than their non-Indigenous peers. It was also noted that Term 4 has a low weighted mean absence rate compared with the other three school terms. This begs the question: what is causing the apparent reduction in absences in Term 4?

While no attempt can be made to attribute causality, something appears to have motivated students to attend class during Term 4. A possible explanation for the decrease that occurred in Term 4 could be, in part, attributed to a school calendar that did not have as many fee-paying activities such as out-of-town excursions. One could also argue that students' returning to school in Term 4 are over the winter sickness period and are motivated by "fun" events that typically occur in Term 4. Nonetheless, these results suggest that attendance patterns are certainly worth investigating in future implementations of the program.

Discussion

This research was driven by literature that posits local, socially constructed Indigenous knowledge involving hands-on activities with appropriately modified language and which takes full advantage of existing Western knowledge systems, strengthens Indigenous engagement and learning outcomes. The learning space in which students' participation in the ISS intervention was socially constructed, in which the local Indigenous community and its knowledge served as inspiration to many. This provided an opportunity to deliver Western science concepts mapped to the Australian National

School Science Curriculum. This middle ground was deemed the ideal setting for optimum engagement.

Implications for the teaching practice showed a way that could potentially transform how Indigenous knowledge can be valued and used in the science classroom. The sharing of local sky stories as a precursor to introducing Western astronomy concepts inspired some students to articulate their own cultural night sky stories and seek out further cultural stories about the night sky. The cultural sky stories seemed to motivate some of the students to observe the actual night sky in their own time. Aikenhead (1996) argues that if teachers provide a cultural “border-crossing” that operates between Indigenous knowledge systems and new knowledge systems i.e. Western astronomy concepts, positive student learning outcomes can emerge. More broadly, Rennie (2006) maintains that curriculum development should include a negotiable space where teachers can mediate between traditional knowledge and practices and Western ways of knowing. The results from our research highlight that this should be respectfully done with elders and other Indigenous community members.

Students were able to articulate their fascination with the night sky after learning cultural stories and astronomy concepts taught in the classroom. To some extent, our results are consistent with the findings of an Australian School Innovation in Science and Mathematics project *Wildflowers in the sky* (Tytler et al., 2008) and with research that posits establishing ties with the local community strengthens learning and engagement outcomes for students (Bhathal, 2008; Howard & Perry, 2005; Mack et al., 2012; Oscar & Anderson, 2009). The night observation event was considered a success (statement by principal) due to the unexpectedly high attendance and participation of both Indigenous and non-Indigenous families. It was also interesting to note the pattern that emerged from the absence data which broadly suggested that overall there were more students at school in Term 4 than during any other term in the school year.

Research (Hauser et al., 2009; McKinley et al., 2008) suggests that keeping students within the school system can be achieved when curriculum-based science legitimises Indigenous knowledge systems.

The ISS program may have the potential to deliver significant and long-lasting changes to the way the astronomy content of the NSC is taught to Year 5 and 6 primary school students. The study showed that introducing cultural sky stories using local Indigenous community members engaged and primed Year 5 and 6 students to investigate astronomical content mapped to the NSC. Consistent with other research (Harrison & Greenfield, 2011; Mack et al., 2012; Oscar & Anderson, 2009), developing collaborative relationships with the local Indigenous community to locate and deliver sky stories was key to the engagement of the students. The successful inclusion of local Indigenous knowledge into a science program has provided a valuable template for teachers to emulate and which can act as a model for the requirement in the NSC to include Indigenous perspectives. Furthermore, concepts from the program may also be useful as a basis for adoption in other subject areas included in the National Curriculum.

Our results indicate that when Indigenous knowledge is recognised and given space within the curriculum, positive engagement may be achieved. Students were fascinated with the cultural stories about the night sky and were motivated to seek out both cultural stories and scientific facts to broaden their knowledge. Further research, therefore, needs to be undertaken more broadly to investigate the efficacy of the inclusion of such Indigenous perspectives in other educational programs or interventions. An opportunity also exists to investigate the impact of the program on students’ science content knowledge in relation to the standards set by the NSC.

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Connective statement

The paper titled Indigenous Sky Stories: Reframing how we introduce primary school students to astronomy – a Type II case study of implementation explored how cross-cultural learning may have contributed to increased engagement at one case-study school in NSW, Australia. The pilot study showed that students were both captivated and primed to learn curriculum-based Science and Technology materials after being engaged with local cultural stories about the night sky. The study also showed that when students are given the opportunity to engage with local, placed-based knowledge, strong links between students, the school and community were able to be established or extended.

The paper introduced the reader to the dichotomy of Indigenous and Western knowledge systems in science education. Along with key literature in the field of Indigenous education in science, two seminal articles were identified. One, argues teachers need to help students navigate between the two opposing systems using a *border-crossing* analogy (Aikenhead, 1996). The second article theorised a third space coined the *cultural interface* (Nakata, 2007). By blending positive aspects from both knowledge systems, opportunities are created to acquire new understandings (Nakata, 2007). Literature concerning the integration of Indigenous knowledge into the science curriculum in terms of how much or how little was outlined to show the, as yet, unresolved nature of this field of research.

The third paper in the series is titled *Working towards a contemporary understanding of mutual cultural responsivity in school science: An Australian perspective.* The paper sets up the expanded research program that includes Year 5–8 students. The paper offers to realign how we can view the contested theoretical space that exists between Indigenous and Western knowledge systems. *Mutual Cultural Responsivity* is introduced as an appropriate addition to the cultural competency framework. Teaching and learning resources discussed in this paper are located in Appendices R–U.

Chapter 4: Paper 3

Evidence of submission

Paper 3 – Working towards a contemporary understanding of mutual cultural responsivity in school science: an Australian perspective. Paper 3 was submitted to the journal Cultural Studies of Science Education (CSSE) on 7 December 2018 and is currently under review (Appendix O).

Paper 3 – Working towards a contemporary understanding of mutual cultural responsivity in school science: an Australian perspective

Nicholas Ruddell, Lena Danaia and David H. McKinnon

Abstract The way in which science curriculum is implemented within Australia continues to be dominated by the Western science model. The hegemony of Western science remains firmly in-place. This is despite a growing body of work that suggests effective science delivery systems should engage with Indigenous communities, their epistemologies and their aspirations.

This paper discusses and realigns the way we view the theoretical space that exists between Western and traditional Indigenous knowledge systems within middle-school science. To illustrate how educational projects might work in this contested middle-ground, an Australian-based middle-school science project that blends both perspectives, and which is focused on astronomy, is described. The project has been implemented in 30 Australian schools. Using a narrative approach, we reflect on how educational projects might work in this contested middle-ground. This method allows for the inclusion of a *Mutual Cultural Responsivity* as each culture must exchange and respect knowledge and perspectives. The middle-ground approach favoured here is an entity in its own right, is a shared space containing legitimate perspectives, informed awareness of alternative cultures and, a vessel that provides the necessary knowledge that is relevant to the individual. In middle-school science settings, there appears to be little research that maps the cultural competency framework to educational programs. Furthermore, there are few Australian programs that integrate Indigenous and Western knowledge systems in astronomy. We contend it is timely that we move toward pedagogical frameworks that include both Indigenous and Western knowledge systems equally. Hard science can and should adopt knowledge diversity and cultural relevancy to promote a socially just learning space by offering multiple points of entry. We need

to develop programs that reach the higher levels of the *Mutual Cultural Responsivity* framework in order to move towards a contemporary understanding of school science for *all* Australians.

Keywords: Education · Science · Cultural · Indigenous · Responsivity

The way in which science curriculum is implemented within Australia, as for other first world countries, continues to be dominated by a Western science model. The current manifestation reflects several centuries of American, British and European political and technical dominance. This hegemony remains firmly in-place despite a growing body of work that suggests effective science delivery systems need to employ Indigenous epistemologies and perspectives (e.g. Brayboy and Castagno 2008).

The imperative to offer a fresh approach is illustrated in Australia where, despite considerable attention being given to improving science education, Australian student performance in Trends in International Mathematics and Science Study (Thomson et al., 2017) and Program for International Student Assessment (OECD 2018) continues to flat-line, or decrease, compared with other countries. Analysis reveals that Indigenous performance falls at least two years behind non-Indigenous performance. This is despite the fact that the *Closing the Gap* initiative, over the last 10 years, has attempted to address these inequalities of educational outcomes between Indigenous and non-Indigenous Australians (Productivity Commission 2016). While positive news relating to Indigenous learning outcomes in the tertiary domain are evident (DET 2016), serious performance differences persist in both elementary and high schools (Commonwealth of Australia 2017).

The major problem this paper attempts to address is finding the common ground in science education. First, the theoretical space that exists between the hegemony of

Western science and traditional Indigenous knowledge in science education is discussed. Second, a different way of working with the emergent cultural interface is offered. Third, we propose a new level to the extant "cultural competency" framework, commonly employed in the Australian setting, to include "cultural responsivity" (Perso 2012). Finally, we illustrate how educational projects might work in the highly contested "middle-ground" by describing an Australian-based middle-school science project that blends both knowledge systems and which is focused on astronomy.

Epistemological tensions: a brief history

While authors have attempted to unsettle the Western science hegemony (e.g. Aikenhead and Elliott 2010) the bulk of the literature is based on where Indigenous science education should sit in a curriculum heavily influenced by the need to resolve the epistemological tensions between Western notions of science and Indigenous knowledge systems. As early as the 1970s, Stephen Harris (1977) began developing ideas around decolonising knowledge to create a workable solution to the problem of having such diametrically opposed systems. In Australia during the 1980s, two opposing theories entitled *Two-Ways* and *Both-Ways* emerged. One maintained that Indigenous and Western knowledge systems should remain *separate,* while the latter argued that students should be exposed to both Indigenous knowledge systems *alongside* Western constructs (Harris 1984). These issues are now considered.

Olugbemiro Jegede (1995) proposed *the theory of collateral learning* in an attempt to deal with the conflict of how students, raised in traditional Indigenous settings, react to the science they encounter when they go to school. Focussed on conflict resolution, Jegede (1995) describes two positions while acknowledging a third middle ground as possible. The first, Jegede (1995) argues, is that if left alone, a student can choose either the Indigenous or Western explanations depending on the problem at hand. The second is that a student can hold onto both ways of knowing and resolve the conflict by integrating elements of the Indigenous and Western knowledge systems (Jegede 1995).

The debate took a conceptual leap forward in 1996 when teachers were asked to provide a greater role in helping students navigate the space between Western and Indigenous knowledge systems. Influenced by Henry Giroux's (1992) book *Border Crossings: Cultural workers and politics of education* and Arlene Stair's (1994) *cultural broker* concept, Glen Aikenhead (1997) articulated a pathway for Western science teachers to reconceptualise themselves as *guides* tasked with acknowledging a student's personal perceptions and worldviews before introducing the alternative culture of Western science. While Aikenhead moves beyond the notion of 'folk science' (Pomeroy 1994), he maintained that the space between authentic Indigenous and Western knowledge systems exists as a cross-cultural border. Nonetheless, the border-crossing metaphor sets the two knowledge systems in two separate places. Moreover, Aikenhead (1997) continued to advocate for students to move away from their traditional belief systems into the Western science way of knowing.

Motivated by the need to improve educational outcomes for Indigenous learners, Martin Nakata (2007) advanced the debate by configuring a *cultural interface* as a legitimate meeting place between Western and Indigenous epistemologies. Constituted by multiple sets of relationships and realities, Nakata (2007) places the two systems alongside each other so that perceived differences can be identified, barriers dismantled and a common ground established. As a consequence, a recognition of an authentic Indigenous theoretical standpoint is articulated (Nakata 2007). The seminal conceptualization remains the benchmark description of this overlapping and highly contested knowledge domain. Annamarie Hatcher et al. (2009) sought to operationalise the interface in practical ways by documenting Mi'Kmaq elder Albert Marshall's "Two-Eyed Seeing" approach. Framed around the idea of mutual respect, science students were taught to interact with both mainstream and traditional ecological concepts by learning to use one eye with the strengths of Western knowledge, the other eye using traditional knowledge and then, to use both eyes together. Using mathematics curriculum as the driver, Elizabeth Warren and Eva deVries (2010) showed that Indigenous learning outcomes and engagement were improved when Math programs were contextualized towards their environment, language was modified and the local community was included. That is to say, the middle ground was the socially constructed cross-cultural space in which local Indigenous knowledge is informed, but not dominated, by Western science systems.

The literature also covers the integration of Indigenous knowledge into the science curriculum on a spectrum of how much or how little should be employed to effect successful outcomes. For example, at one end in New Zealand, Elizabeth McKinley and Georgina Stewart (2012) take the position that Maori students should be fully immersed into Western science using their Indigenous dialect, practices and knowledge. Towards the other end of the spectrum, Damian Larkin, Donna King and Gillian Kidman (2012) report on a study that adheres to science investigative procedures that adopt only a superficial treatment of Indigenous knowledge.

Understanding the personal lives of students and establishing strong community relationships appear to be critical to the success of culturally embedded curriculum design. This was shown by Elizabeth Mack et al., (2012) who found that student engagement could be strengthened by using locally sourced language, knowledge, and hands-on practices informed by developing strong, collaborative relationships with the Indigenous community.

Similarly, Ragbir Bhathal (2008) showed that hands-on astronomy programs involving the community were a successful way to engage students with the high school science curriculum. Designed to help improve scientific literacy, a series of cross-cultural, astronomy activities successfully engaged 15 junior secondary Aboriginal students.

Consistent with research that examined the benefits of community involvement with schools (e.g. Oscar and Anderson 2009), the project's success was attributed, in part, to the attendance and participation of parents and the local community at evening observation sessions.

The tendency for academics to focus on the development of educational theory was challenged by Soenke Biermann and Marcelle Townsend-Cross (2008) who articulated the need for further research into different Indigenized teaching strategies. They argued that one such alternative could be an Indigenous pedagogy based on the ideologies and belief systems of Indigenous Australians. While the teaching strategies they employed to integrate Indigenous perspectives appeared sound for the sample of students presented in their study, providing content relevancy to Indigenous groups across the continent of Australia was thought to be problematic because of the variety of language groups and different Dreaming Stories across the nation.

The theoretical and practical studies presented above appear to show a workable middle ground between the current hegemony of Western science and traditional Indigenous ways of knowing. Here, the middle ground employs local, socially constructed Indigenous knowledge, hands-on activities, and appropriately modified language to take full advantage of existing Western science knowledge systems to stimulate student engagement and positive learning outcomes. Based on the findings of Warren and deVries (2010) and consistent with the research reviewed thus far, a science curriculum that effectively integrates elements from Indigenous and Western knowledge systems appears to be the appropriate model.

To some small degree the mandatory inclusion of Indigenous perspectives in the Australian Science Curriculum (ASC) reflects the need to move towards the middle-ground approach and, despite being contentious (e.g. Austin and Hickey 2011), teachers are required to deliver science that embeds cultural knowledge. However, the number of

Indigenous perspectives mandated in the ASC and its obligations for teachers to develop an appropriate praxis is not the subject of this paper. At issue is the deeply troubling question of why, given the Australian research presented above, the ASC mandate and subsequent government-initiated programs there is no discernible progress being made in the learning outcomes of Indigenous students in Australia?

Debate amongst academics has evolved from having a Western Science system that dismisses all others (e.g. Gross and Levitt 1994), through a recognition of an alternative Indigenous knowledge system that is not equal to Western Science (Battiste 1986), then through legitimising Indigenous knowledge before moving to the Western Science approach (Aikenhead 1997), and finally to a blended but contentious middle-ground model (Nakata 2007). As a methodology and a body of knowledge, the impact science has had on Western thinking has led to the perception that it is the only legitimate way to determine what constitutes "true knowledge" (e.g. Martin and Mirraboopa 2003).

Working in the middle ground space: research methodologies

Resistance from researchers, in the form of anti-colonial, anti-hegemonic strategies, argue for research methodologies that align to the needs and protocols of specific Indigenous groups. For example, Mason Durie (1996) proposed a two-knowledge-system solution for the Maori context in New Zealand. This was conceptualized around the notion of bi-culturalism involving an integration of both Pakeha (a non-Indigenous New Zealander) and Maori cultural perspectives. This system was designed to eliminate the perception that Pakeha would remain in control of Maori Knowledge. The system also acknowledges Maori intellectual property and the need for Maori to moderate the inclusion of Pakeha perspectives.

Lester-Irabinna Rigney (1999) proposed a theory that offers a workable, independent framework to conduct research with Australian Indigenous peoples. The approach provides an Indigenized paradigm that offers a more holistic and respectful approach, which fully acknowledges traditional protocols. Karen Martin and Booran Mirraboopa (2003) employed Rigney's (1999) theory to develop a clearer indigenized research framework that draws on Quandamooka (Northern Queensland language group) ontology and epistemology. More significantly, the author positions her new paradigm "*Ways of knowing, Ways of Being, Ways of Doing"* as a stand-alone discourse while recognising Western methodologies as being yet another.

This holistic approach can be recognized in other Indigenous methodologies, most notably the now widely practised Kaupapa Maori Research Methodology (KMRM) from New Zealand. Drawn from historical constructs and grounded in Maori language, KMRM stresses cultural respect, reciprocity, adherence and acceptance of protocols, and guidance from both tribal Elders and other significant members of a community (Smith 1999). The phrase "*by Maori, for Maori, with Maori*" concisely articulates the desire for self-determination and firmly sets the path for cultural perpetuity (Smith 1999).

Articulated through the lens of colonized peoples, these methodologies provide the vehicle for heterogeneous Indigenous groups to take control of the research process by forefronting specific traditional knowledge systems and practices as a counter to the hegemony of Western science. Key to the process is the emphasis on a "*nothing about us, without us*" approach. Supported by national and international documents on Human Rights, the de-colonialization process heralds the reclaiming of both traditional and contemporary knowledge and ways of doing and being (O'Sullivan, Hill, Bernoth and Mlcek 2016). The collection and sharing of data are viewed as a reclamation of heritage and represent, through granting permission, a healing process (Muller 2014). Holistic and socially-just approaches afford both the Indigenous and non-Indigenous researcher with opportunities to work in an agreed second space, that is to say, a reconstituted middle-ground.

In light of this emerging literature, we argue that in the sphere of educational design, the middle-ground model is imperfect and further examination of this cross-cultural space is required. That is to say, the cultural lens through which the middle-ground space is viewed, remains, both culturally and institutionally, one dimensional at best. The aforementioned research suggests that both Indigenous and non-Indigenous students must work at the *Cultural Interface* using an identical set of lenses, one using Indigenous knowledge and the other Western scientific knowledge. In practice, however, all students employ unique perspectives gained from their personal lives to engage with Western science in order to 'pass' mandated science learning outcomes. Thus, given that there are differences within and across Indigenous and non-Indigenous groups, the homogenised two-group model is fundamentally flawed.

For Indigenous students, the current Western science model is culturally inequitable and, despite allowing for Indigenous perspectives to be included in some small way, no real improvement in learning outcomes is being detected (OECD 2018). Nakata (2007) places the two systems beside each other and uses any common ground to configure a workable solution in the middle. This potentially allows teachers to include Indigenous perspectives as a way to engage students before they are inevitably asked to conform to the Western hegemonic model.

We contend that the two knowledge systems should remain separate with a third space at the intersection reserved to represent the middle-ground. On their own terms, Indigenous students engage with their own knowledge system before the Western scientific model. Subsequently, they then engage with the knowledge overlaps of the middle ground space. The same method applies in reverse for non-Indigenous students. Imagine two students wearing eye glasses with different colored lenses for each eye. The Indigenous student looks at the science content first through a red and then a green lens to represent understandings generated by their Indigenous perspectives and then by the Western science content. A non-Indigenous student uses their eyes to look through yellow and orange lenses. Each lens is a different color for each student to represent the fact that students bring different cultural perspectives through which the information is viewed and interpreted. The color of each lens is a metaphor to represent individuality. Thus, each student sees and learns about both their own and the other's knowledge system before working in their own personal "middle-ground" with both eyes open. This approach allows for a mutual "cultural responsivity" as each individual must recognise, understand and appreciate the knowledge and perspectives generated by the two systems.

The "middle-ground" approach favoured here is an entity in its own right, is a shared space containing legitimate perspectives, informed awareness of alternative cultures and, a vessel that provides the necessary knowledge that is relevant to the individual. The middle ground accepts that hard science can and should adopt knowledge diversity and cultural relevancy to promote a socially just learning space by offering multiple points of entry. Ideally, crossing over from an Indigenous to a Western hegemonic system is no longer required.

It is here that we introduce the twin concepts of "cultural competency" and "cultural responsivity" and a framework for helping assess the extent to which individuals are developing both competency and responsivity. Originally developed for the health sector in the 1980s and used widely in the United States of America and New Zealand, momentum for the implementation of "cultural competency" programs in Australia increased dramatically after the Royal Commission into Aboriginal Deaths in Custody (Dodson, O'Dea, Wootten, Wyvill and Johnson 1991) cited a systemic culture of inadequate and inappropriate professional interactions with Indigenous individuals and communities (Universities Australia 2011). Cultural competency training is now part of government and commercial sector core-employment capabilities (Bean 2006).

Australian universities have committed to embedding cultural-competency training for all employees and, as a consequence, a best practise framework has been developed (Universities Australia 2011).

A wide range of definitions for cultural competency are available for review (e.g. Barrera and Kramer 1997). In the context of the teaching space K. Lee, B. Cosby and D. deBaca (2007) define cultural competency as:

> A set of congruent behaviours, attitudes, and policies that come together in a system, agency or among professionals and enable that system, agency of those professions to work effectively in cross-cultural situations (Lee 2007 et al. p. 3, cited in Perso 2012).

We note here that the inclusion of the word congruent is interpreted to mean congruent with the expectations of Indigenous Australian peoples (Universities Australia 2011).

While not exclusive, (i.e., Bennet's *Developmental Model of Intercultural Sensitivity* (1998, cited by Hammer, Bennett, and Wiseman 2003), Marcia Wells (2000) further developed the cultural competence construct to produce a framework. This appears to be an appropriate one for our discussion because it describes the orientation of systems and organizations, and can be used by an individual (Universities Australia 2011). The framework comprises six stages:

1. Incompetence
2. Knowledge
3. Awareness
4. Sensitivity
5. Competence
6. Proficiency

This framework focusses on attitudinal and behavioural change that can be tracked as individuals, groups or systems develop knowledge that enables effective and positive experiences when working with Indigenous people and/or their communities. Policies and strategies of systems and organisations should reflect the hierarchical and developmental nature of cultural competence. Table 1 presents Wells' (2000) Cultural Competency staged definitions.

Table 1: Cultural Competency Matrix

Stage	Description
Cultural incompetence	Lack of knowledge of the cultural implications of behaviour
Cultural knowledge	Learning the elements of culture and their role in shaping and defining behaviour
Cultural awareness	Recognizing and understanding the cultural implications of behaviour
Cultural sensitivity	The integration of cultural knowledge and awareness into individual and institutional behaviour
Cultural competence	The routine application of culturally appropriate interventions and practices
Cultural proficiency	The integration of cultural competence into one's repertoire for scholarship (e.g., practice, teaching, and research). At the organisational level, cultural proficiency is an extension of cultural competence into the organisational culture. For the individual and the institution, it is mastery of the [five preceding] phases of cultural competence development.

Adapted from Wells (2000, p. 192)

Based on the Wells (2000) model and the research of Hilary Weaver (1999), Rob Ranzijn, Keith McConnochie, Andy Day and Wendy Nolan (2006) developed a matrix that maps the six stages of cultural competence against six elements relating to knowledge, attitudes and skills. Figure 1 illustrates the developmental nature of cultural competency with the developmental Criteria at left and the Stages extracted from Table 1 for the individuals who are the targets of the training.

Behaviour / Criteria	Cultural Incompetence	Cultural knowledge	Cultural awareness	Cultural sensitivity	Cultural competency	Cultural proficiency
Professionally specific skills						
Cross-cultural skills						
Critically examining the profession						
Reflexivity of values and attitudes						
Understanding Indigenous cultures, histories and contemporary issues						
Generic understanding of culture						

Figure 1: The Cultural Competency Matrix (Ranzijn, McConnochie and Nolan, 2006)

Figure 1 outlines a process that begins in the lower left-hand corner for those who are culturally incompetent and progresses upwards to the top right hand corner in the case of participants who are culturally proficient. While an arrow shows an upward trajectory, the development of cultural competency is an ongoing journey that follows no specific start, path or end point (Ranzijn et al. 2006). Indeed, the individual strengths of a person, system or organization could, in fact, place them at any point on the Matrix not necessarily on the path indicated in Figure 1. For example, an organization may be placed midway on cultural awareness in their understanding Indigenous cultures and histories while at the same time being culturally proficient in the area of critically examining the profession.

While the criteria, in the left-hand column of Figure 1, have been contested (Farrely and Lumby 2009), the adoption of the cultural competency framework provides a way of looking at, and reviewing, the cultural identity and worldviews of a system or an organization. Congruent with the expectations of Indigenous Australians, engaging with the Matrix represents an acknowledgement and willingness to let go of outdated colonial structures of power to work in an educational space that respects, and indeed needs, multiple points of entry to prosper. Following Maureen Fitzgerald's (2000) comments about "developing empathy and connected knowledge, the ability to see the world through another's eyes, or, at the very least, to recognize that others may view the world through different cultural lenses" (p.184), it also affords the target of the training to look at the world from an Indigenous perspective. Once participants, systems or organizations have acquired the capacity to articulate their attempts to be culturally competent, a response in the form of a service or delivered outcome can be generated.

Beyond cultural competence and first conceptualized in the USA, the term "culturally responsive" is used to frame strategies designed to engage an ethnically diverse audience in culturally viable ways (e.g. Cazden and Leggett 1981). From the early work conducted in the 1980s, a Culturally Responsive Pedagogy (CRP) emerged (Gay 2000). Key elements such as cultural and linguistic immersion, awareness and nurturing of the cultural knowledge that students bring to school, modified curricula and constructivist teaching strategies are strongly advocated (e.g. Richards, Brown and Forde 2007).

In Australia, Thelma Perso (2012) extended CRP to mean "Cultural Responsiveness is enacted Cultural Competence" (p.22) with both Aboriginal and Torres Strait Islander students being included as the audience. Key influences unique to Australia include the "8-Aboriginal Ways of Learning" framework (Perso 2012) for Indigenous students. This inter-linked set of pedagogies employs a place-based narrative approach that incorporates traditional learning concepts and is based on story-telling, community links, symbols and images, land links and spirituality (Yunkaporta 2009).

The need for teachers to embed CRP into their daily practice is articulated multiple times in the seven-point framework of the Australian National Professional Standards for Teachers. They are:

1. Knowing students and how they learn;
2. Knowing the content and how to teach it;
3. Planning for and implementing effective teaching and learning;
4. Creating and maintaining supportive and safe learning environments;
5. Assessing, and providing feedback and reporting on student learning;
6. Engaging in professional learning; and,
7. Engaging professionally with colleagues, parents/caregivers and the community.

(Perso 2012, p. 62)

We propose that *Mutual Cultural Responsivity* should be included as another level in the existing cultural competency frameworks. We define *Mutual Cultural Responsivity* as a pathway for communities of culturally competent participants to produce learning experiences that satisfy a collective goal. It is noted here that even at this level, all participants would still need to be continually engaged with the development of "capacity and response" (Perso 2012, p. 22). That is to say, M*utual Cultural Responsivity* is offered as an additional component to highlight the necessity of delivering programs that are designed for, and with, the entire informed school community.

Joe Kincheloe and Shirley Steinberg (2008) argue that along with acquiring content knowledge, an educator must have an understanding of both Western and Indigenous ways of knowing and must accept that using knowledges "cannot be separated from the worldviews and epistemologies embraced by their producers" (p. 149). Brian Brayboy and Angelina Castagno (2008) also recognise the diversity in knowledge construction and argue for curriculum design and pedagogies to bypass Western and Indigenous 'ideas' in science learning in favour of acknowledging and reflecting different 'worldviews' of science learning. According to Jon Austin and Andrew Hickey (2011) a "multi-logicality pedagogue" (involving many ways of knowing) is the most effective method to teach in the middle ground described by Nakata (2007) as the *cultural interface*. It is argued here that breaking away from the confines of one-truth Western science explanations provides teachers with a fresh pathway to locate and value alternative knowledge constructs (Kincheloe and Steinberg 2008).

Confronted by this complex domain, in middle-school science there appears to be little, if any, research that links the cultural competence framework, described above, to these educational settings. Furthermore, there are very few Australian educational programs that integrate Indigenous and Western scientific knowledge systems in astronomy. In the next section, we describe one science education project that is mapped to the modified cultural competence framework and which appears to have potential in this highly contested middle-ground.

Overview of the Sky Stories science project

Sky Stories followed a successful pilot program called Indigenous Sky Stories and involved 19 New South Wales elementary schools (Ruddell, Danaia and McKinnon 2016). Both projects blend current science understandings with Aboriginal knowledge of astronomy in order to capture the interest of Australian middle-school students (Grades 5–8) in school science. Research suggests students of this age are often turned off science because of the transmissive way in which it is taught (e.g. Goodrum, Druhan and Abbs 2012). In contrast, Sky Stories employs a culturally relevant, interactive, investigative and technologically-driven approach to engage students in astronomy, a science domain about which the majority are often fascinated. The program includes professional development, extensive learning materials and support to enable teachers to deliver the pedagogies referred to above including Roger Bybee's (1997) 5E learning model, 8-Ways and place-based education all of which map to the Australian Curriculum as well as the modified cultural competency matrix (Ranzijn et al. 2006). Community involvement was a major component of both projects. The overall goals of the projects were to provide opportunities for addressing the performance gap between Indigenous and non-Indigenous students; expanding teacher cultural content knowledge, competence and confidence; localising 'stories' in school communities; building an online community that engages with, and shares ideas about, teaching science and cultural perspectives to middle school students and, working towards a contemporary understanding of cultural competence in school science.

Sky Stories integrates Western and Indigenous knowledges systems in astronomy. It involves Aboriginal students and their class peers exploring cultural stories about the night sky, practicing investigative science and supports their teachers in developing their pedagogical skills to deliver Australian Curriculum science content. An integral element of the project is accentuating the links amongst individuals, families, communities and their sky stories. The links enable new ways of learning and teaching, and involve community engagement in school science. Given the importance that the Australian Curriculum places on ensuring Indigenous perspectives are integrated into school science programs, it was anticipated that the program would be of value. In Sky Stories, students are provided with opportunities to engage with, and explain their understandings of the natural world from multiple frames of reference. Underpinned by Mutual Cultural Responsivity, a blend of CRP, 5Es, 8-Ways and place-based pedagogies are used to deliver the Sky Stories educational curriculum.

Grounded in the cultural competency framework, CRP is used to deliver modified, inclusive learning experiences to a culturally diverse audience (Gay 2000). Consistent with Vygotsky’s social constructivist theory, student achievement is promoted through the awareness and nurturing of identity and prior knowledge (Lev Vygotsky 1980). Creating a culturally informed, safe learning environment, providing strength-based, student-centered learning and, involving local community are key components of CRP (e.g. Elizabeth McKinley 2016).

The 5Es instructional model is a common framework used to deliver science teaching and learning. Developed by Roger Bybee (1997) and later adopted by the Australian Academy of Science, the 5Es model has gained astonishing momentum through the National Primary Connections program (Hackling, Peers and Prain 2007). The initiative provides a framework for student-centered, inquiry-based science learning (Skamp and Peers 2012). The 5Es pedagogy, which includes professional development and support, is supported by the Australian Federal government and the Australian Academy of Science (Peers 2006). The 5Es are Engage, Explore, Explain, Elaborate, Evaluate, each phase of which defines both teacher and student behaviours in the investigative process. All 5E phases can employed within one lesson or collectively over a whole unit of work.

The 8-Ways set of pedagogies were developed to assist teachers to engage effectively with Aboriginal knowledge and to assist in identifying a common ground with Western knowledge systems (Yunkaporta 2009). The framework is described as a point of entry into "Aboriginal ways of knowing, doing and being" (Yunkaporta 2009). Figure 2 illustrates the interplay of the eight pedagogies and represented by the interconnected symbols. This interconnectedness is defined by: the protocols (story sharing and Learning Maps), the processes (non-verbal and Systems and Images), the systems (land links and Land links), and the values (deconstruct/reconstruct and community links). It is noted that while attempts to embed Indigenous perspectives into the science curriculum can be achieved, no outright commitment to officially integrate 8-ways into conventional teaching pedagogies has emerged (e.g. Yunkaporta and McGinty 2009).

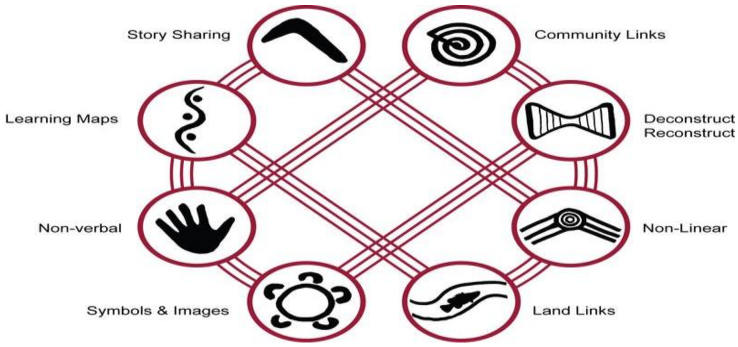

Figure 2: The 8-ways set of pedagogies (Yunkaporta 2009)

Another pedagogical framework employed in Sky Stories is “place-based education”, which is grounded in the belief that natural learning occurs best when people, local environments and purpose are interconnected (Gruenewald 2003). Characterised as a student-centered pedagogy, learning programs are designed to engage students with their immediate and unique physical and cultural environment beyond the school fence. The pedagogy seeks to contextualise science learning by tasking students to investigate topics of local and personal relevance. With its origins dating back to the early 1900s, place-based education re-emerged in response to concerns that standardised testing, currently favoured by contemporary education systems, offers little time for students to develop autonomous inquiry skills that focus on problem-solving issues connected to their own lives (Buxton 2010).

Smith (2002) identifies six elements of place-based education programs:

1. Students and teachers engage with actual phenomena around them
2. Students are creators not consumers of knowledge
3. What is studied is determined by questions and concerns generated by students
4. Teachers’ act as “guides, co-learners and broker of community resources and learning possibilities” (p.593)
5. *Reciprocity* of knowledge between students and community

6. Student learning outcomes are assessed on capabilities and whether or not a contribution has been made to the community.

Given the autonomous nature of teaching, integrating CRP, 5Es, 8-Ways and place-based pedagogies is both a professional choice and a complex domain in developing and promoting cultural responsivity by teachers. As with all the components of the Sky Stories project, the researchers continue to collect teacher feedback to ascertain the delivery systems that worked best to suit their local conditions.

Components of the Sky Stories Project

Teaching and learning materials. Schools are provided with comprehensive educational packs containing a stage-3 (primary) or stage-4 (high school) unit of work, Aboriginal astronomy learning content, a telescope, instructional videos and targeted social media. Interrogation of the impact of the learning materials provided for the Sky Stories pilot program (Ruddell, Danaia, McKinnon 2016) coupled with an extension of the program into high schools led us to simplify the offering for later iterations.

More specifically, a six-lesson unit of work, drawn from Primary Connections *Earth's place in Space* were developed for Grades 5 and 6 (elementary school). The unit contains lesson plans, teacher notes, curriculum links, additional resources, tutorials and hyperlinks to electronic resources. Along with English and Mathematics, teachers have the opportunity to integrate Creative Arts. The first lesson introduces students to the positional relationship between Earth, Moon and Sun. The second lesson introduces students to an alternative knowledge system, that is to say, Aboriginal astronomy. The remaining four lessons guide cooperative learning groups, each made up of four or five students, to construct models and present their theories of celestial position and movement. The unit also tasks students to investigate characteristics (size and distance) of objects within the Solar System.

A second unit of work containing an optional 15 lessons and linked to the Earth and Space Sciences strand of the National Curriculum was developed for Grades 7 and 8. Learning materials are drawn from the *Science by Doing* project and provided on an online website funded by the Federal Government and managed by the Australian Academy of Science. *Science by Doing* provides teachers and students with digital learning resources that promote investigative science practices using the 5Es pedagogical approach. Students can work independently by following modules that include tutorials, virtual tours, videos, and interactive assessments. A proportion of the *Science by Doing* digital resources are sourced from Scootle, an online portal set up by the Australian Government Department of Education (Australian Academy of Science 2017). The site houses lessons, assessments and teacher planning materials. Scootle allows teachers to accumulate, and digitally store, targeted resources, called a learning path, for students to access later via a personal identification number.

An additional 14-page booklet containing activities that explore day and night, the seasons, phases of the Moon and the Solar System was offered in conjunction with, or as an alternative to, the *Science by Doing* and *Scootle* resources. The booklet was produced after teachers, surveyed in 2013–14, suggested that the learning materials offered in the pilot program were too dense or too difficult to use. A private science communication firm was sourced and commissioned to provide a shortened, edited booklet focussed on four key astronomical learning areas; the Moon; Seasons; Night and Day; and the Solar System.

While Indigenous histories and cultures are embedded in the *Primary Connections* and *Science by Doing* units, all students and teachers are provided with additional targeted cultural learning materials assembled by the research team. Aboriginal astronomy resources included links to grade-appropriate and teaching-practice literature, videos, websites and blogs. A lesson was also prepared with the assistance of the Aboriginal

Education Officer employed by our university. The lesson investigates a Wiradjuri (a large central-west language group located in New South Wales) narrative concerning sustainable fishing linked to calendrical celestial phenomena.

On the basis of feedback from teachers who complained about the lack of appropriate materials we provided a set of cultural learning experiences for inclusion. Teacher feedback also prompted the Sky Stories team to provide introductory and instructional videos. These included an overview of the program, how to build your telescope, how to organise a cultural night sky observation event and, a personal dreaming story by a local Wiradjuri female, senior Elder.

Each participating school was given an 8-inch Dobsonian telescope, a sun filter and three eye-pieces. Teachers were asked to allow student groups to build the telescope to generate a feeling of 'ownership'. Two instructional videos showing how to build, and how to set up and operate the telescope were prepared and made available via the university website and through social media. Professional development for teachers

The delivery of professional development (PD) for participating teachers, and the collection of data from the process, are key features of the Sky Stories project. Learning and teaching materials were designed to build cultural competency, confidence, science content knowledge and investigative pedagogical skills.

During the pilot phase of the Sky Stories project (Ruddell, Danaia, McKinnon 2016) the PD program took the form of an intense one-day face-to-face session. The Sky Stories team modelled science pedagogies and simulated activities designed to encourage cooperative, investigative science teamwork. The training included short tutorials on how to put together the donated Dobsonian and how to use, and connect to and operate a remote controlled telescope in the USA. Based on teacher feedback, a shorter series of face-to-face and online workshops for both primary, secondary principals and teachers were developed for the expanded Sky Stories project. Four NSW regional centers were chosen to act as learning and training hubs for nearby schools. As with the pilot program, teachers and Aboriginal Education Officers were released from their regular classes to attend the PD sessions.

The lead author was engaged to deliver the professional development sessions, which included an introduction into the Sky Stories curriculum package and an overview of Aboriginal astronomy. A general discussion was offered on how to build relations with the local Aboriginal community and how to organise a school-community astronomy observation event. An external professional was employed to teach participants how to work with the social media platform in terms of posting learning outcomes, event news, and their learning and teaching experiences. Face-to-face workshops concluded with the distribution of the donated Dobsonian telescopes.

Video technologies were trialled to broadcast online training from the local Department of Education resource center. The session was recorded to allow teachers to access a condensed version of the face-to-face PD session described above. In both cases, teachers were asked to complete an online survey to evaluate the efficacy of each. Follow-up PD was supported further using social media, telephone-calls and email interchanges amongst the project personnel, the research team and the teachers.

Involvement of teachers, families, Sky Stories personnel and community engagement around science

Attendance and participation of parents and the community has, in part, been shown to contribute to the success of student learning outcomes (e.g. Harrison and Greenfield 2011). The same was true for the Sky Stories project since its inception. However, Sky Stories also attempted to strengthen interest in science-related activities amongst participating schools and their local communities. In addition, links amongst the schools were achieved by employing community observation nights and social media.

Moreover, school communities were afforded access to a broader and more learned community, *viz*., academics at the university.

Night sky observation events. Participating schools, with the support of the Sky Stories team, organized cultural and night sky observation events during the school term. Schools were encouraged to adopt a whole community approach that aligned with the aims of the project to bring the local community together and share Western and Indigenous knowledge about *their* night sky. A typical program included a barbeque, story-telling by Elders, Aboriginal cultural performances including dance, and using their telescope to observe stars, planets and the Moon. During the 2013 pilot program, donated iPads loaded with planetarium software were used to locate planets in conjunction with their telescopes. In later iterations, privately owned smart phones and digital tablets were used.

Since the inception of the project, schools have employed a range of hardcopy and digital media to publicise, and report on, their night observation events. Invitations, often designed by student teams, were published in local newspapers, school newsletters and websites, and through social media and local radio stations. The 'bush telegraph' (word of mouth) played an important role in getting information to families, particularly in the more isolated rural areas of Western and North Western NSW.

In order to cope with the typically large turnout at these observation events, schools often collaborated by sharing their telescopes with each other, with three or more telescopes often being available. Telescopes were manned throughout these events by Sky Stories staff and local enthusiasts to ensure families had plenty of opportunity to view the Sun, the Moon, Venus and later, various planets and stars in the night sky. Each telescope had a chair alongside it to allow small children to access the eyepiece. Smart phones were used to capture digital images through the telescope eye piece.

Holding the smart phone steady proved to be a major impediment to securing a clear image. In response, telescopes were retrofitted with a robust smart phone bracket.

Contributions in the form of food, advertising and night sky knowledge were supplied by schools, parent committees, local cultural and networking organizations, and small businesses. In one example of small-town generosity, the local Parent Teacher Association supplied food, plates and utensils for over 200 guests. In another small town the forestry department donated the barbeque meat for 150 guests. Cultural knowledge in the form of advice, stories, dance and displays, was provided by, or with the permission of, local Aboriginal groups and Elders. Members of the Sky Stories team and local astronomy clubs provided expertise in the field of astronomy and assisted with the operation of telescopes.

Social Media. Social media was employed to provide a communication hub for schools, the wider community and the Sky Stories team to contribute to, and follow, the progress of the Sky Stories project. This initiative is consistent with the overall project aim of building an online community that engages with, and shares ideas about, teaching science and cultural perspectives to middle school students and to their local school community. The Sky Stories team published “How to” videos, cultural stories, astronomical images, fast facts, research and professional learning notices on the social media platform.

Participating schools contributed in two ways. First, teachers used social media as a learning hub to share ideas and resources. Second, teachers posted digital images of student learning in science, for example, making solar system models, constructing and using their telescopes, and presenting cultural performances and other artworks. Social media also served as a notice board for individual schools to post details about future Sky Story events or images showing school community attendance and participation.

Links and contributions were accepted from related social media groups who showed an interest in the program, for example, Aboriginal groups, astronomers and academics. Participating schools often linked the project social media with their own accounts in order to communicate with their own school community. It is important to note here that Sky Stories social media was professionally moderated and protected against inappropriate use.

Project management and participants. The Sky Stories project has inducted staff from over 30 schools drawn from regional New South Wales and Eastern Victoria. Thus far, approximately 50 teachers and over 1,100 students have been involved. During the pilot phase, the overall project was managed by researchers belonging to the School of Teacher Education at Charles Sturt University (CSU). From 2014 onwards, Sky Stories was managed within the University by Future Moves, a Higher Education Participation and Partnerships Program (HEPPP) funded by the Federal Government. Future Moves focuses on delivering middle school awareness programs that encourage students to consider a university education. Sky Stories is one activity within the ‘Danygamalanha’ (‘to excel’ as defined by Future Moves) suite of activities where students and community are encouraged to participate in Science, Technology, Engineering and Mathematics based curriculum through the exploration of astronomy. Outreach programs such as the Sky Stories, form an important link between CSU and schools across NSW and North Eastern Victoria.

Participant schools in close geographical proximity are organized to simplify area management and to allow common professional learning sessions at regional centers. The proximity groups also allow for collaboration amongst primary and high-school science teachers and to encourage co-operation amongst schools. Each proximity group is managed by an area coordinator who is responsible for the area. In addition, a Sky Stories reference group was formed to oversee the implementation of the program. The group membership comprises: CSU Future Moves management and area coordinators; researchers in the School of Teacher Education, CSU; members of the CSU Indigenous Australian Curriculum and Resources team; and, an independent social media professional.

Educational research. Underpinning the program is a body of educational research that aims to investigate both the impact of the project on students' perceptions of science, and their emerging knowledge and understanding of Indigenous and Western science concepts. The educational research also explores the impact of the project on teachers' perceptions of science and science teaching from both a Western and Indigenous perspective. Students and teachers also have the opportunity to provide feedback on their experiences within the Sky Stories project to help inform subsequent iterations of the project. The educational research associated with this project is the focus of a number of papers, for example, pilot data are presented in Ruddell, McKinnon & Danaia (2016) while more recent data from the evolved project is still being collected and analysed.

Conclusion

This paper has examined the theoretical space that exists between the hegemony of Western science and traditional Indigenous knowledge in science education and has proposed a different way of working within this cultural interface. We have also examined the existing cultural competency framework and proposed a new level involving *Mutual Cultural Responsivity.* This new level could be a pathway for communities of culturally-competent participants to produce learning experiences that satisfy the goals of both the Indigenous and non-Indigenous populations.

The Australian-based Sky Stories project that blends both perspectives is one example of how a middle-school science education project might work in this highly contested middle ground. Unfortunately, Western science perspectives continue to dominate the science curriculum in Australian schools. Now, with an Australian curriculum that embeds Indigenous perspectives throughout, it is timely that we move toward pedagogical frameworks that include both Indigenous and Western knowledge systems equally. In schools, we need to develop programs that reach the higher levels in the proposed *Mutual Cultural Responsivity* framework in order to move towards a contemporary understanding of school science that is inclusive of *all* individuals.

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Connective statement

The paper entitled *Working towards a contemporary understanding of mutual cultural responsivity in school science: An Australian perspective* explored Mutual Cultural Responsivity as an approach designed to extend our understandings of how to operate in a reconstituted space between Indigenous knowledge systems and the Western hegemony in school science. The purpose of the paper was to establish how the research has progressed to its current form thus providing the background and context for the dissertation.

The paper explores the process of locating a workable space that serves both learning approaches and worldviews equally. The discussion highlights an upwards trajectory in Indigenous theory development. Key Indigenous research frameworks are introduced to show critical examples of resistance to the Western hegemony of science research practices.

Implications from the research suggest that operating in a middle-ground space may provide a viable solution for both researchers and the school communities on which this dissertation is focussed. To illustrate how this emergent theory might work, the 30-school Sky Stories program was described in detail.

Having reached a critical understanding that positions the research inside a culturally responsive, middle-ground space, the fourth paper in the series investigates the impact the Sky Stories teaching and learning initiative had on teachers, students, members of the community and project-related personal. The paper unpacks a theoretical approach that offers researchers a culturally appropriate pathway for future research in the field of cross-cultural science education. The paper argues that the middle-ground provides the optimum conditions for place-based research, teaching and learning to emerge. Using anecdotes and data from field research the article unpacks the Mutual Cultural Responsivity framework as a way of showing cultural competency “in-action”.

Chapter 5: Paper 4

Evidence of submission

Paper 4 – Enacting the middle-ground: An approach using Indigenous sky stories. The fourth paper in the series was submitted to the *Australian Journal of Indigenous Education* (AJIE) on 8 January 2019 (Appendix P) and is currently under review.

Paper 4 – Enacting the middle-ground: An approach using Indigenous sky stories

Nicholas Ruddell, David McKinnon

Abstract

This article discusses a theoretical approach that offers researchers a culturally appropriate pathway for future research in the field of cross-cultural science education. The middle-ground can provide the optimum conditions for place-based research, teaching and learning to emerge. Critical to the success of conducting research in this space is a guiding model that enriches the capacity building cultural competency matrix. Using data collected during field research, *and being mindful of confirmation bias*, this article unpacks the Mutual Cultural Responsivity model as a way of showing competency in-action. The framework provides the means in which one can assess and develop a response using three stages: Awareness, Becoming and Being.

Keywords: Science Education Community Indigenous Mutual Cultural Responsivity

The mandatory inclusion of Indigenous perspectives in the Australian Science Curriculum (ASC) reflects the need to move towards a research, teaching and learning space that can successfully operate between Indigenous and Western knowledge systems. To varying degrees of success, education professionals now embed cultural knowledge into their daily routines across Australia. The issue is inherently political and as such, relies on policy that is subject to the political imperatives of the day. That is to say, the inclusion of cultural aspects in the ASC could be dismantled during any political cycle of any future government. For example, as recent as 2018, a candidate (unsuccessful) standing for the Victorian State election called for it to be dropped in favour of a back to basics platform (ABC 2018).

The inclusion of cultural perspectives into the curriculum provides exciting opportunities for education researchers to describe exemplars of how it can be done successfully, and what reactions or impacts, if any, result from such studies. However, a discussion of cross-cultural education generally is not the purpose of this paper. Rather, this article is to theorise an approach where cross-cultural school science education research can occur in authentic and ethical ways. We draw on data and examples from a cross-cultural science-education project to illustrate how this theory might be employed in practical ways.

A recent review of Australian and international cross-cultural school science research showed that research design and, in particular, data collection, can be problematic in terms of delivering actual outcomes for the community of people who are involved with a school (Ruddell, Danaia, & McKinnon in review). Despite operating in a cross-cultural domain involving local Indigenous communities, the vast majority (42 out of 50) of field studies used Western orientated practices and methodologies to frame their research. Of the 110 studies reviewed, the authors found that the bulk of the literature explored affective qualities (attitudes, behaviours, engagement) using mostly qualitative data collection procedures. Cognitive (thinking, learning, and reasoning) datasets that could have shed light on the acquisition of knowledge or understandings constituted only a minor component of the research data. There appeared to be little to no exchange of findings or resources offered to the participants, Elders and/or their communities.

Despite research to the contrary (e.g., Singer, Bennett-Levy & Rotumah 2015), the normal modus operandi for non-Indigenous researchers appears to be a top down approach which favours institutional obligations over the wants and needs of communities that the research purports to be helping. It seems logical that cross-cultural school science research, and more broadly, research involving Indigenous peoples more generally, should place the aspirations of the school and community at the forefront. Currently, two very separate paradigms are in play.

The first paradigm firmly holds itself at the top of a socially constructed knowledge hierarchy in support of the continuing Western knowledge hegemony. Science research methodologies usually require a positivist approach. Ideally, quantitative data collection is extracted from participants and used to explain cognitive understandings in a results-driven design (e.g., Danaia, Fitzgerald, and McKinnon 2013). Theoretically, researchers maintain a dispassionate mindset that interrogate numerical data-sets. Generally speaking, outcomes are not usually communicated to participants or their community for dissemination. Indeed, results are often presented in such a way that the data are meaningless or irrelevant to the Indigenous communities.

A second paradigm offers Indigenous researchers a critical set of methodologies to bypass traditional notions of research. Indigenous methodologies favour cultural standpoint theories that reflect a more holistic design. While not exclusive, qualitative data collection methods are often used to explain affective attributes and are normally coupled with an equal acknowledgement and inclusion of the research journey experienced by both the researchers and the participants (e.g., Yunkaporta & McGinty 2009). In this paradigm, researchers have an obligation both to consult and to act on the directions of Elders and significant members of the community, to adhere to formal protocols, and to offer reciprocity. Language is often a key component underpinning the design (Smith 1999). Reporting results in a way that is discernible and useful to all participants and communities, in which the research may not be the central component (e.g., Hatcher, Bartlett, Marshall & Marshall 2009), is a clear aspiration within this paradigm.

Exploring a third, culturally appropriate and culturally responsive domain that considers and uses aspects from both paradigms would appear to offer researchers a more flexible option. Exactly how this domain is configured has been a contentious debate and has yet to be accomplished.

Academics have been trying to resolve the epistemological tensions between Western notions of science and Indigenous knowledge systems for well over three decades. Theories that either offer to configure, or circumnavigate, a third space has given researchers valuable tools to frame their studies. The list below shows some of the theories offered to navigate cross-cultural science education since the 1980s.

- Stephen Harris (1984) Two ways & Both ways
- Ritchie and Butler (1990) Bicultural science education
- Henry Giroux (1992) Border Crossings
- Elizabeth McKinley, Pauline McPherson Waiti and Beverley Bell (1992) Bilingual education
- Arlene Stairs (1994) Cultural broker
- Olugbemiro Jegede (1995) Collateral learning
- Glen Aikenhead (1997) Border Crossings/Cultural Broker
- Marilyn Fleer (1997) Two-way learning
- Martin Nakata (2007) Cultural interface

Our research operates within the cultural interface first conceptualised by Nakata (2007). Recognising the need to articulate a contemporary theoretical standpoint for Indigenous Australians, Nakata (2007) argued that the cultural interface is a legitimate third space between Western and Indigenous epistemologies and ontologies. Founded on the idea that multiple sets of relationships, intersections and realities are in constant motion, Nakata (2007) positions the two systems beside one another so that differences can be identified, barriers dismantled, and a common ground established. The conceptualisation is seminal and, in our view, remains the benchmark description of the highly contested dichotomous domain.

In this article we use a middle-ground framework to underpin cross-cultural school science education research. In earlier work (Ruddell, Danaia & McKinnon 2016), the middle-ground was defined as a "… socially constructed cross-cultural space in which local Indigenous knowledge is informed, but not dominated, by Western science systems" (p. 172). Conceptualised as a legitimate, critical entity in its own right, non-Indigenous researchers operating in this space should have the cross-cultural awareness, knowledge and self-assurance to adopt a proactive stance that relegates the discussion around Western hegemony and decolonisation to the sidelines. Bypassing such unhelpful and distracting narratives allows the middle-ground to move to the centre stage (Smith 2003). The middle-ground has multiple points of entry and, as a result, can accommodate multiple points of view and perspectives. Furthermore, it forefronts cultural responsivity in-action by offering inclusive, culturally respectful practices and priorities that give equal importance both to the outcomes and to the research narrative.

The middle-ground approach draws on critical research that posits the need for a contemporary science education framework that can exist simultaneously with and between the two ideologies (Ruddell, Danaia, McKinnon, in review). Spanning several decades, the literature (e.g. Brayboy & Castagno 2008) also shows that there is a need for holistic science research, teaching and learning approaches that are compatible with the needs and wants of the community. Our view is that when collaborative non-Indigenous researchers conduct studies in school communities the inclusion of Indigenous researchers, coupled with Indigenous methodology considerations, should take precedence.

Highly credible examples of Indigenous research frameworks are available for review. For example, in Australia the Gamilaraay (a South Eastern language group) worldview is employed to demonstrate how a holistic approach can lead to equal outcomes of practice and results. (Yunkaporta & McGinty 2009). Martin and Mirraboopa (2009) offer the Quandamooka (a Northern Queensland language group) methodology to demonstrate Indigenous research sovereignty. New Zealand's Kaupapa Maori Research (Smith 1999) and the Inuit-Qaujimajatuqangit (Inuit traditional knowledge) framework from Canada (e.g., Higgens 2014) demand a full recognition of values, systems and protocols congruent with the expectations of Indigenous peoples. Key here is the idea that research should not be allowed to occur in the cross-cultural domain without the explicit approval and involvement of Indigenous Elders and/or significant others associated with the community in which the research is to take place.

Thus far we have established the cultural interface as the theoretical domain in which we are operating and highlighted the middle-ground as an area of this domain that can be used specifically for cross-cultural science education research. Critical to the success of conducting research in this space is the need to engage with, and learn from, informative cultural guides and frameworks. One such guide, based on the Wells (2000) model, and adapted by Australian universities, is the cultural competency matrix. The guide offers a continuum pathway for practitioners, organisations and systems to develop and accumulate levels of knowledge, skills and values (Ranzijn, McConnochie, Day & Nolan 2006). By continually reflecting on one's own position on the 6-stage matrix, practitioners are able to recognise that their own viewpoints may not be identical or compatible with the views held by others. The cultural competency matrix establishes an acknowledgement and preparedness to work with post-colonial ideas about educational practices such as inclusiveness, empathy and respect. Once participants, systems or organizations have acquired the capacity to articulate their attempts to be culturally competent, a response in the form of a service or delivered outcome can be generated.

With researchers in mind, we offer the Mutual Cultural Responsivity framework as a way of showing “competency in-action”. We define this as a pathway for communities of culturally competent participants to produce research and experiences that satisfy a *collective* goal. That is to say, Mutual Cultural Responsivity is offered as an additional component to highlight the necessity of delivering science education programs that are *designed for, and with, an entire, informed community*. We emphasise, in the context of this study, “entire” means researchers, teachers, the local Indigenous Australian community and the broader school community of which they are all a part. Non-Indigenous participants acknowledge, engage, and identify with their *own* knowledge system before being introduced to a second system. Subsequently, they then learn how to engage with the knowledge overlaps in the *middle-ground space*. On their own terms, the same method applies for Indigenous participants. The Mutual Cultural Responsivity model guides each individual to see and learn about both their own and the other knowledge system and worldviews, and then provides pathways to work in their own *personal* middle-ground. The framework provides the means by which individuals can enter the middle ground through being immersed in the three stages of Mutual Cultural Responsivity: Awareness, Becoming and Being. We unpack these three stages as follows.

Awareness

In this stage, participants reflect on whether they have gained an awareness of culturally appropriate and inappropriate actions and attitudes. Through “experiences” that are mostly gained in the field, participants arrive at the understanding that there is a problem with the way in which their research or teaching is communicated to, and conducted within, schools and local communities. These “experiences” will vary for individual researchers. However, we, as non-Indigenous researchers, have found the learning curve to be steep and, often confronting. At issue here is the need to slow down, to listen and to suspend the judgement that is a powerful feature of certain ways of thinking and acting. The Awareness Stage allows for this to be tackled in a constructive "first-attempt fashion".

Typically, funded research is designed with tight time constraints in ways that very often conflict with Indigenous ways of doing. That is to say, researchers are, or have been, in a hurry. This is a conflict because the usual social construction of Indigenous groups requires consultation over an extended period of time. Additionally, outcomes that align with Indigenous people's wants and needs are often forsaken in favour of Western, academic or institutional imperatives. While there are many contemporary examples, these are reflected in literature published in the early 20th century (e.g., McDougal 1903, cited in Nakata 2007).

The Awareness Stage thus identifies disconcerting issues that ultimately cause the researcher to question her/his practice leading her/him to reframe or re-design her/his approach. In all cases, a transformation must take place. The researcher will realise in the contemporary world of science education research that guidance needs to be sought and certain protocols need to be followed when interacting with communities who have Indigenous members. Without this consciousness on the part of the researcher, progression to the next stage is not possible.

Becoming

Having recognised the need for a more holistic approach when working with schools and their local communities, the researcher and the participants within the study enter into the Becoming Stage. It is here that actions take place that will ultimately define a cross-cultural science education program. The participant understands and appreciates the dialogical exchange of knowledge and perspectives generated by two distinct knowledge systems, that is, traditional and contemporary Indigenous and Western science knowledge systems. Indeed, our personal research journey has been influenced by our need to assess the extent to which we have attained a professional level of Cultural Competence and Awareness and, once acquired, what responses we can offer in the form of services, support or outcomes desired by the community. Personal reflection driven by a deep engagement with Cultural Competency frameworks such as those provided by Ranzijn, McConnochie, Day and Nolan (2006), and Personal Standpoint Theory (Nakata 2007) allow for continued self-appraisal of one's capacity and response to work in the cross-cultural research domain both effectively and ethically. While not exposed to the theories named here, communities are also required to reflect on their involvement, their motivations and their aspirations when opportunities are made available. Providing services, knowledge and time in the spirit of reciprocity are seen as critical here. As in the first stage, we operate in the *middle-ground* domain. Consistent with Nakata's (2007) interface narrative, and given our personal social, institutional and historical standpoints, we argue there can be no single truth, no one intersection. We can say with clarity, however, that when researchers provide multiple points of entry and adopt knowledge diversity and cultural relevancy within their research, then socially-just and meaningful science education outcomes can occur for the entire community.

Becoming Stage participants attempt to provide authentic opportunities for heterogeneous Indigenous groups to contribute their own specific knowledges and practices that can work alongside Western school science approaches. This emphasises the idea that cultural knowledge and practices need to be included with the direct involvement of the local Indigenous community. Employing personal and professional perspectives allows the researcher to initiate culturally respectful practices and priorities that give equal importance to both academic and community aspirations. From an Indigenous perspective, inclusion signifies the importance and relevance of place-based cultural knowledge. More broadly, the inclusion of local Indigenous perspectives represents a reclamation of heritage leading to a healing process for the community.

The Becoming Stage allows for holistic, proactive approaches that afford participants the opportunity to work in an agreed third space, that is, the middle ground. Key here is the acceptance that conducting research within communities is a privilege, not a right. It is in this way we can perhaps move towards a contemporary understanding of how socially-just and meaningful school science can be implemented for all.

Being

The Being Stage is the middle-ground space of cultural confidence. Practice has evolved to where Mutual Culturally Responsivity is commonplace. Ethical, culturally appropriate research, with a high degree of scrutiny by both the researcher’s institution and the community, has to be enacted before, during and after programs are introduced. Potential outcomes that are beneficial to the community are placed at the forefront of the endeavour. Drawn from the pioneering work of Indigenous scholars (e.g., Rigney 1999) the phrase “not about us without us” applies here. In this space, collaborations between Indigenous and non-Indigenous researchers allow for dominant methodologies to be bypassed in favour of more holistic designs. The concept of allowing “sufficient time” to consider the multiple viewpoints is understood and practised by all. That is to say, establishing and maintaining relationships, giving and receiving feedback, resourcing, and answering to institutional and community imperatives requires “sufficient time” to be congruent with the expectations of that community. The ability for both parties to exchange knowledge, perspectives and resources cannot be overstated here.

Being Stage participants understand that human relationships and interactions sometimes break down and that this time-consuming ebb and flow is the normal state of human affairs. Being Stage participants also have to advocate continually for culturally appropriate protocols, procedures and practices so that relationships can be nurtured and issues resolved. Moreover, Being Stage participants are adding to the social capital of the entire community as traditional culture and cultural knowledge intersects with the contemporary world. In terms of academic engagement in this stage, a deeper, more personal research paradigm is able to be articulated and used as an exemplar for future studies. These shared experiences allow for the co-construction of a new, sustainable social memory that is respectful of the past, mindful of obligations, forward gazing and, ultimately, aligned with the needs and wants of the community.

In sum, this study is underpinned by cultural interface theory in which we advocate the use of the middle-ground framework to articulate appropriate research practices suitable for working in the cross-cultural science education research domain. We operate in this space with cultural confidence and by doing so, we employ the Mutual Cultural Responsivity framework to articulate our understandings. In this research, the journey and results are described by presenting and interpreting findings in a particular way that illuminates both Indigenous and Western needs and wants.

Context of the study

Informed by a twelve-month, 19-school pilot program, the Sky Stories program is an educational research project that uses a blend of Western and Indigenous knowledge to teach astronomy to Australian middle school students. It involves students exploring traditional cultural stories about the night sky and practicing investigative science both in and outside of the classroom. Funded by a Higher Education Participation and Partnerships Program (HEPPP), the broader Sky Stories program involved an additional 30 NSW schools over a two-year period. The program supports teachers in developing their pedagogical skills to deliver science content mapped to the Australian Curriculum.

The Sky Stories project provides access to learning and teaching materials that give students the opportunity to engage with, and explain their understandings of the natural world from multiple frames of reference. Integral to the overall project was the involvement of local knowledge holders and the community. Teachers and Aboriginal support staff were brought together in area clusters for a single face-to-face professional learning session. On-going support was provided via telephone or digital communication. Using a dedicated website, a project introduction, materials, orientation and instruction on social media was provided. To encourage interaction between teachers, students, the local community and the Sky Stories support team, schools were also given access to a dedicated social media site in which digital resources such as instructional videos were presented. Following the professional development session, representatives from each school received teaching materials and a 20-centimetre Dobsonian telescope, a solar filter and three eye-pieces as a gift. A full description of the Sky Stories program is available in an earlier publication (Ruddell, Danaia, & McKinnon, in review).

Method

This research works towards a holistic understanding of how to conduct cross-cultural science education research in schools. A case-study design was used to collect multiple sources of data from multiple locations (Yin 2014). Teachers, students, Aboriginal Education Officers, members of local community, program personal and researchers were involved in the cross-cultural science education program. To illustrate the progression of the research, anecdotes from a smaller, pilot program held two years earlier are used. Using a modified multi-perspective analysis (Pal 2001) we draw on technical, organisational and personal perspectives to illustrate the strength of the three-stage mutual cultural responsivity framework, and to articulate the research journey undertaken.

The case-study involves research and support staff, and multiple participants in a single school. The teaching team was chosen from a potential pool of 28 middle-schools (Year

5–8) that participated in the broader Sky Stories project. While many of these schools contributed to the program in terms of teaching and learning data, the case-study teaching team expressed an interest in closer contact and support from the outset and was in close proximity to the researcher. The case-study team was considered to be an ideal data collection site because:

- The principal and staff whole-heartedly supported the implementation of the program
- Teachers were organised into a specialised team
- All teachers attended professional learning sessions
- Individual teachers attempted to teach programs related Western Science concepts
- Elders introduced cultural stories to the students
- The teaching team organised a community night observation event involving cultural sky stories and night-sky observations using telescopes
- The teaching team provided pre and post data sets and interview data
- The teaching team produced and posted digital artefacts related to the program on social media.

Located in a rural town on Wiradjuri country (Central Western NSW), the case-study teaching team consisted of one supervisor who taught a composite Year 5 and 6 class, two teachers who taught Year 5 students, and one teacher who taught Year 6 students. The public primary school has a school Index of Community Socio-Educational advantage (ICSEA) of 923 with the average ICSEA being 1000. The school enrolment averages 430 students with 19% Indigenous students (ACARA 2018). The local Wiradjuri community is well represented in the school. Except for science, various arts and literacy programs were either in place or had been trialled before the Sky Stories program was adopted. The school has a good ongoing relationship with Charles Sturt

University. Cooperation between academics and teachers includes an annual placement of pre-service teachers. The school has Wiradjuri support staff who work alongside students and teachers. A senior Wiradjuri Elder was known to staff and was a regular visitor. While the team appeared confident, some cultural discomfort was discernible. Typical of primary school organisational practices, all teachers in the team were the regular classroom teachers.

Over a 12-month period, the lead researcher met with the case-study teaching team during the professional development and orientation programs, in-class observations and interviews, and at a night-time school community event that involved story-telling and observing various objects in the night sky. Electronic communications and phone support were maintained throughout the year. Team leaders, teachers and university project personal were interviewed in a flexible fashion, depending on the responses during the interview. Teachers were asked about the effectiveness of the program in terms of the learning materials, professional development and community engagement. University project personal were asked for their assessment of the overall program in terms of implementation and management.

Findings

As mentioned in the previous section, a variety of data sources were used in this study. While these data will be used to highlight the impact of the Sky Stories program, we cannot wholly describe the journey of research that was undertaken. Our aim is to describe the successes, failures and lessons learnt by the entire community of Sky Stories participants as we progressed through the program. We have identified the middle-ground domain as a culturally appropriate learning environment, and advocate for the employment of the Mutual Cultural Responsivity model. Two questions are organised to explore each of the three stages: Awareness, Becoming and Being.

Question one: What experiences occurred when preparing and conducting the Sky Stories research program?

Awareness

We start this analysis by offering some observations noted during the beginnings of the Sky Stories program. When the initial idea of conducting research involving Indigenous knowledge was raised, we attended a meeting of the local Aboriginal Education Consultation Group (made up of Aboriginal Elders and respected Aboriginal community members and educators) to put forward a pitch for participation. Approval and guidance to find local knowledge holders and story-tellers was sought. No immediate response was provided. As the weeks went by, the research team, alarmed at the evaporating research program window, decided to seek additional ways to progress the research plan.

During this time the team learned that an Elder was visiting our campus so a fortuitous and impromptu meeting occurred. During this meeting the team expressed their frustration that despite instigating a top-down approach, no information had been forthcoming. Observation notes recorded after the meeting note that:

> Uncle suddenly put his head down and stared at the table top. It became apparent he no longer was willing to listen or talk about our program. After a short silence, he looked up and said that first and foremost we were asking a Biripi man for information about Wiradjuri practices. He then said, brusquely, "You fellas need to stop talking. You need to shut up and listen!" (Observation notes, November 2012)

On another occasion soon after, the team attended a research forum that included three visiting Maori academics from New Zealand. When told about our experiences finding appropriate knowledge holders and story-tellers, they responded by offering the following statement.

> When you are looking for a pharmacist, you don't go into a bank to ask for a prescription do you? (Observation notes, November 2012)

After both meetings we were struck by the simple but practical advice. Pushing against a culture that honoured the need for time to contemplate our requests was a serious mis-step. The issue of allowing time when conducting research in Aboriginal communities is seen as critical.

Funding was provided to release teachers and Aboriginal Education Officers for a single, all day, Sky Stories professional development and orientation program. The first cluster was held in a rural area and was well attended by principals, teachers and Aboriginal Education Officers (AEO). Cultural mis-steps occurred from the outset when, after introductory announcements were made, the speaker turned to the only male participating AEO and asked if he could present a Wiradjuri “Welcome to Country” (a formal ceremony welcoming visitors to Country). Two issues were apparent here. First, if the research team had asked, they would have been told that this AEO, while respected, was not the appropriate knowledge holder who could perform this ceremony. Second, because we did not provide prior warning, a shaming of this AEO took place in front of his peers. At best, and with notice, an “Acknowledgement of Country” (acknowledge the presence of Elders past and present, and the Country on which the event is to happen) conducted by a local Indigenous member would have been appropriate. At issue here was our culturally inappropriate assumption that the male Indigenous person must know the cultural practices and could do this “Welcome”. We were quickly disabused of this assumption by the senior female member of the language group who offered a lesson in protocols and who then extended the Acknowledgement of Country and Elders past and present to all. Had the research team been culturally aware, inquiries would have been made well ahead of time to ensure the appropriate person would perform the ceremony.

Another issue that was observed during the professional development sessions was the demand that all night-sky related equipment donated to each school would be given to the school AEO. Subsequently, a high-end telescope with various attachments, and an iPad loaded with sky mapping software was handed over without prior consultation. The announcement caused some embarrassment to the AEOs as science teachers vocalised that they thought they would have had unfettered access to the equipment. Some AEOs expressed frustration that they had nowhere to store the equipment in their care. Others said they had no idea how to operate the telescopes and were confused as to why they had not been asked about it. Others said they were confused about their role in the program and were alarmed at the angry responses of teachers. Our intention had been to empower AEOs by putting them in charge of the hardware and software. Instead, due to our lack of consultation, the team's demands led school staff to direct their anger at the AEOs in terms of their ability to look after the equipment. Some went as far as to question the reliability of the AEOs. The issue raised for us disturbing warnings of potential underlying racism within some schools. Observational notes recorded after the professional development sessions included comments from teachers such as the following:

> The equipment will go missing.
>
> We'll never see it [the telescope or iPad] again.
>
> They're never here [at school].
>
> They'll lend it out to their mates. (Teacher conversations, Observation notes, April 2013)

A key component of the Sky Stories program was to involve the local community in a night sky observation event involving a BBQ, cultural story-telling and observing various celestial objects (e.g., the Pleiades star cluster, the Moon, Saturn). Teachers said they could easily invite parents and families to an event but in relation to local Aboriginal knowledge holders, school staff were indifferent. Two recurring issues arose from this conversation. First, many teachers were exasperated that the Aboriginal community did not show any interest in the school and, with the schools' teaching programs.

> We've tried to involve them [the local Aboriginal community] in the past but they're not interested. They don't talk to us. They never get back to us. (Teacher conversations, Observation notes, April 2013)

Second, because they had little to no positive relationships in place, some teachers said they that they would have little opportunity to locate knowledge holders.

> They don't want to tell us about their traditional culture. We wouldn't even know where to start looking for someone. (Observation notes, April 2013)

We witnessed many other instances of victim blaming throughout the program. In almost all cases where a lack of engagement was commonplace, the local Aboriginal community was thought to be at fault. Inter-generational trauma, previous invasive research practices, disrespect and ineptitude may be leading factors here. It was noted at the time that, generally, schools wanted examples of traditional, static knowledge that they could implement on their own and without consultation. The more contemporary realities of Aboriginal life did not appear to be relevant. We take up this conversation in the next section.

Our missteps highlighted here were restricted not only to our own ignorance but also to our cultural incompetence. Seeking to address the literature base (e.g., Fitzgerald et al. 2014) suggesting teacher content knowledge in astronomy is limited at best and non-existent at worst, our aim was to provide high grade teaching resources. A high quality, 300-page tome providing an integrated approach to teaching astronomy, with many options, in the primary school was provided to each teacher free of charge. From the outset, teachers told the team that it was "confusing" and "too long", as only four or five teaching lessons were allowed for the topic during their teaching/learning programs. Despite this feedback, we assumed that they had read the short section that clearly stated that they had to make choices about what to include to meet their curriculum needs, for example, the seasons, night and day, Moon phases and the Earth's position in relation to the Sun. Nonetheless, for the rest of the pilot program teachers had to sift through the lessons. Our view was that the contents were clearly marked and that more effort by the teachers was required.

The multiple instances of candid feedback we were getting from participants, coupled with our own experiences was of great value to the team. Despite the significant challenges, overall enthusiasm shown by schools and the research team remained high. To help facilitate the aims and purposes of the research, and produce a science teaching and learning program that authentically involved the Aboriginal community, it was clear a more concise approach needed to be formulated.

Becoming

During the summer break and into the following year a reworked Sky Stories program was conceptualised and implemented. The need to listen to the wants and needs of the program's participants was seen as paramount to the success of the new program. A Sky Stories reference group was set up to oversee the implementation. Headed by a project manager, the group included managers and area coordinators from the university's school outreach organisation, Indigenous curriculum specialists, researchers and an independent social media professional. A Wiradjuri man was also engaged to act as a cultural liaison between schools, community groups, the AECG, Elders and the Reference Group members. This led to positive dialogue among all parties and formed the basis for ongoing relationships.

Mindful of the need to allow plenty of time to develop these relationships, potential participants were informed of the program during the 2014 school year with the goal of implementing it a year later. Groups were also given the option of implementing the program in 2015, in 2016, or both. Reacting positively, one Reference Group member was recorded as saying that the program:

> … took on a new shape. We had new tools to offer which interested schools, particularly ways to build the Sky Stories community such as social media.

Providing a website and access to dedicated social media was in response to the need for improved communications and a mechanism to deliver free resources to a wide audience. Along with new digital teaching and learning resources, informational videos such as how to build the donated telescope and how to organise a community night observation event were posted. Additional content was provided by the lead researcher in the form of a comprehensive list of books, videos and website links. In the spirit of reciprocity, a senior Wiradjuri Elder allowed the research team to film and post a video of her re-telling her own sky story. In another example, a Wiradjuri woman collaborated with the lead author to provide a lesson plan on a calendrical night sky story involving sustainable fishing.

Overall, attempts at setting up practical communication and consultative practices across multiple platforms, providing the environment whereby cultural knowledge was freely offered, donating teaching and learning materials, and allowing time for participants to absorb information, were all well received. Having learned the lessons from the pilot study, the research team had entered into the Becoming Stage and as a result, 30 schools accepted our invitation to implement the program.

Being

Setting up and conducting the Sky Stories program over a four-year period provided valuable experience to take into future research, teaching and learning in the cross-cultural science education domain. Designing, consulting, waiting and reciprocating are key attributes that are known, practiced and continually reflected upon. Being Stage participants understand their role within a project because communication is clear, respectful and guided by cultural protocol that empower individuals to act, to question, to reflect and to do.

Reflecting on examples of reciprocity, the 2014–2015 Sky Stories project manager discussed her involvement in helping organise a cultural night sky event for the case-study school. After helping out with some of the organisational aspects, including transporting Aunty to the event, she had spent the rest of the night operating one of the four telescopes, engaging with families and talking to many visitors to the school.

> "…one of the great outcomes from helping out at the school night [event] was I got to ask the AEO if she knew of any didgeridoos we could borrow for a year 9 high school camp I was putting together… [The camp was for year 9 Indigenous boys who were coming to the university from remote communities across the state] … a little while later she came back with three of these amazing looking digeridoos and then another guy (an AEO from a nearby high school] gave me his personal 'didge'. I was amazed but so happy to get them for the boys" (Interview notes, 2016).

Clearly, a trusting relationship had been established prompting an exchange of resources. The project manager went on to talk about the online professional development program that was offered to participants who, for a variety of reasons, could not travel to the face-to-face sessions.

> "the [online] PD [professional development] worked well in my opinion, there was such a big geographic spread for people to come to a central point… costs like teacher relief and travel time came into it. It worked well and I think this will work in the future especially for teachers in far off locations" (Interview notes, 2016).

The usefulness of the list of cultural resources provided via the Sky Stories website was raised by the lead researcher. The main concern was that teachers would not adopt a culture of inquiry for themselves and their students. The project manager observed that:

> 'They were pretty good, but once you get a feel for what the program is all about, there are other places to go to get those. Once a teacher accessed one of those things [items from the list] they didn't find it difficult to just go independently … with their research …" (Interview notes, 2015).

When asked about the level of support that would be required for the second year of the program, the project manager was confident that:

> "This year's schools can run with it now, only new schools need that level of support" (Interview notes, 2015).

The project manager appeared confident that participating schools were operating on a level that would allow for continued positive practices between individuals and institutions. The examples described here appear to show that participants operating in the Being Stage respond spontaneously, generously and with purpose.

> Question two: How did research participants react to the Sky Stories Sky Stories research program?

Awareness

From the outset, the main concern raised by participating schools was the possibility that local sky stories would not be forthcoming due to the lack of, or break down, of positive communications with their local Aboriginal community.

> We can't find anyone to help us out.
>
> They aren't interested.
>
> I wouldn't know where to start, they don't talk to us. (Teacher/researcher conversations, 2013)

As a back-up, we responded with a comprehensive list of books, YouTube videos and website links related to Aboriginal astronomy as part of the teaching and learning resources pack. As the Sky Stories program progressed many teachers chose to use these resources. At best, a local member of the Aboriginal community was invited to school to re-tell a story directly from a list provided by the first author. The research team found this troubling as developing community ties was seen as an integral part of the Sky Stories program. However, the list worked as a double-edged sword: students could be shown an alternative explanation for various celestial objects using a variety of sources, but teachers used these resources to bypass making contact with their local Aboriginal community.

Becoming

Many schools did identify appropriate knowledge holders to deliver cultural content. Often this was done at the school level. In one example, two AEOs communicated with their local Aboriginal Elders who in turn recommended a holder of local knowledge. He was uncomfortable to speak to large groups and, in turn, asked his wife, a Wiradjuri woman who was known to the school community to help out. When questioned about this grassroots process, the AEO said that:

> "... she [the story-teller] isn't a local, but the locals accept her as an Elder in her last town so, with her husband they then sat down and ... he passed on a few stories".

This approach demonstrates the importance of each participant in a process that respects the customs and protocols of the local Indigenous community. Locating night sky stories and presenting them in a way that was culturally relevant and appropriate to students and local sensitivities was a high priority for all participants but particularly the AEOs discussed here. In another example, the case-study senior teacher was asked how she had organised their local content:

> "We looked at the CSU website with the Sky Project. We noticed that Aunty was on there [the website] delivering one of hers [stories], so we were unable to download it at the time but Aunty has a strong connection with our school, so she came along to our Sky Project evening and we sat around campfire and Aunty spoke of her sky stories and delivered those."

Social media acted as a digital notice board for all participants in the program. Teachers, almost all of whom were new to the platform, were trained at professional development sessions who in turn, took leadership of their own schools' online presence. Overall, reaction to the digital resources was positive once security concerns were addressed:

> "Yes, we've begun that journey. We've been researching this year on the value of social media within the school context. From the start, we have had staff at professional development around the appropriate ways to set those up to support our school, to show what our school is doing but also protect our students as well with permission gained".

Providing a platform that would connect communities, and communities of practice was a major goal of the Sky Stories program. When asked to reflect on reaching an audience beyond the school gates one case-study teacher commented that:

> "Social media is a great access to the community and not only locally or regionally but globally as well, the connections."

A variety of digital learning materials were provided to the teaching team. For example, a four-lesson booklet provided succinct, easy to follow lessons plans that encouraged hands on learning activities suitable for both primary and high school students.

> "We found that they were not just at an academic level but they were practical in the classroom and could be used throughout our classroom, no matter what level our students were. They were able to be modified and suited across the range."

Perhaps the highlight of the Sky Stories program, a community night observation event was held near the end of the school term. In a reciprocal arrangement, the case-study school borrowed a second telescope from another nearby participating school and another two were provided and operated by university researchers. Describing their night under the stars, the senior teacher said that:

> "Yes, it was one of the best evenings we've had at school. We opened up the evening to parents and community across the whole school, not just to our Stage 3 students. We seen [sic] many children come along and they had the opportunity to not only view the night sky and listen to Aunty, they were [also] able to enjoy a barbecue or make the doughboys around [the] campfire and just build a sense of relationship and connection within our community as well."

The night the sky was very clear and Saturn and its rings could be seen by astonished families. After the event one case-study teacher commented:

> "… their feedback that they never thought in their life that they would be able to see things like that or to explore that. That was great, how parents had such a positive response."

Instances of individuals offering their own sky story memories occurred spontaneously and without solicitation. For example, one grandmother who was attending the community night observation event said she would not look into a telescope because it would ruin her reality of the Moon. When questioned on this she said that years ago, when living on a mission, her Uncle told her it [the Moon] disappeared in pieces each month because a man was chopping it up for campfire firewood. In another example, Indigenous families who wanted to attend a community night observation event but had no access to a vehicle, the school principal personally drove them to and from the school grounds. Each time she would return to pick up more families she told us that the parents were excitedly "remembering" sky stores from their childhood. "Remembering" that Uncle had told them about the shape of the Moon or what their grandmother had told them about the stars. She said her passengers spoke non-stop about the old stories they had been told and that they:

> "…had not realised they were of value". (Researcher conversation, 2015)

This sharing of personal sky stories was not an isolated event during the Sky Stories program. It appears that in some cases, the program served as a catalyst for individuals to set aside their usually reserved manner and offer valuable insights into stories passed down to them by significant others. For example, one year 6 student had been discussing the Sky Stories program with his father while they were travelling:

> "My dad told me on the way back from Walgett, because the Moon was red, my Dad said that "Remember, when an Aboriginal person dies it goes red" and that is what I believe".

The Sky Stories program brought the community together and allowed teachers and students the opportunity to showcase the types of learning the school had been engaging with over the term. In-turn, the community responded with sky stories and experiences directly related to the night sky. Reflecting on the events of the school term, the team leader from the case-study school said that:

> "I thought what a great opportunity for schools to take on board what was happening in the community, not just at a school level but at a greater level and for our students to see what was out there and have that exposure, to provide that equity, to see what the future holds as well, was great."

Being

Proactive activity that showed communities "owning" their online presence was evidenced throughout the program. For example, social media as a community noticeboard and resource repository proved to be widely accepted once users overcame security issues. Despite being encouraged to use the main Sky Stories social media page, schools quickly moved towards using their own social media to communicate announcements and learning products (e.g., cultural presentations; models of the Earth and Moon; posters about various planets). Asked about the reactions to the Sky Stories social media site, and how it could move into future programs the project manager observed that:

> A lot of schools are already posting their stuff on their own [social media] pages. I think a better way forward would be for us to embrace that practice and get them to just follow us … and maybe forward appropriate content to our central page when they can. We can [in turn] follow and monitor their pages for activity.

In response to questions about how Sky Stories program could influence other aspects of teaching and learning about science, one teacher said;

> "… I know some other lessons that we've been doing, we've put the questions out there for the students and let them explore and research and then come back around to providing that background knowledge after all that brainstorming and research has been put in place." (Teacher interview, 2015)

A reflection and conclusion

Born in New Zealand, the lead author grew up in an environment where, despite having a culturally active Maori father, Western ways were accepted as the dominant norm in the household. The hegemony was perpetuated by my English born mother, her siblings, and my grandparents. Indeed, during my childhood, Pakehas (non-Indigenous New Zealanders) largely chose to remain cloistered in the British colonial system that socially and institutionally repressed a unique and vibrant Maori culture. Opportunities for the lead author to learn Te Reo (Maori language) and Maori cultural practices associated with Iwi (the social unit in Aotearoa, New Zealand) were actively discouraged. For this reason, the lead author can never claim to fully understand the perspectives and contemporary realities of Indigenous Australian 'Being'. Generated from critical understandings that have progressed the lead author's own personal standpoint, the research journey described in this article has produced understandings that nurture a deep empathy of what it means to 'be'. When reflecting on the ability to operate in the Being Stage, the lead author's position has to be constantly checked against, and with, the perspectives and realities of Indigenous Australian peoples.

The second author grew up in Scotland before immigrating to Australia. His journey was prompted by a project involving World Heritage sites, natural and cultural, given to his son while in Year 8. They visited Tongariro National Park in New Zealand, and spent time with the Iwi based there. He was shocked by the story that this particular Iwi had arrived a long time ago and found others already there. The newcomers killed the tribe. Surprised, the second author asked "Why?". He was told that these people no longer had a reason to live given that their land had been taken from them. Deep reflection followed and he came to understand better the Indigenous connections with Country and why it was called their "Mother". Since then, he has been working with language groups in NSW and Western Australia. He has been given an Aboriginal name, Dyiraamalang, and the status of Elder for this work with the local Wiradjuri Nation. He cannot, however, fully appreciate the terrors perpetrated by the colonial system in any personal way. Rather, it is a deep intellectual understanding of their lived realities.

Initially, the research associated with the Sky Stories program was designed to dispassionately report on a science education program that blended Indigenous and Western knowledge of astronomy. As interactions with Indigenous Australian participants increased, it became clear operating within the hegemonic Western way was not possible. Theoretically, a shift or transformation was needed from Aikenhead's (1997) popular Border Crossing metaphor to Nakata's (2007) seminal Cultural Interface narrative. Once identified, a middle-ground space was defined as being the optimal space for conducting cross-cultural science education research.

When initiating an educational program that involves an "entire" community of peoples and institutions, we learned that our needs and wants were not, and should not be, the priority. With justification, research team members were bluntly instructed to stop talking and start listening. Measures were taken to form a collaborative team, however, despite the inclusion of Wiradjuri knowledge holders, taking the extra step by involving Indigenous Australian researchers, would have provided much deeper insights and perspectives. We learned that the research process, if it is to be worthwhile, takes time, and the concept of time cannot be measured against Western, institutional constructs. We also learned that at the foundation of successful interactions with an entire community, reciprocation and respect are the bedrocks of deep and lasting relationships.

In this article we used the Mutual Cultural Responsivity framework as a guide to discuss the progression of cross-cultural, science education research. We argue, the new model could enrich cultural competency training and can potentially move practitioners from a Capacity to Response model when choosing to operate in the middle-ground domain. The Mutual Cultural Responsivity framework is far from complete. Rather, it is part of ongoing critical work that seeks to uncover contemporary ways for institutions to operate with Indigenous peoples of Australia and the school communities to which they belong.

By providing the opportunity for Sky Stories participants to enter and work in the middle-ground space, individuals gained social memories that can be employed in new opportunities for research, teaching and learning. Individuals entered into the world of school science from multiple entry points and this provided fertile grounds for acquiring knowledge. Without doubt, individuals were fascinated by stories. Indeed, for all participants in this study, the story-telling process captivated us and provided new ways of building harmony in schools and the community to which they belong. Intensifying this interest using respectful, educative ways such as those described in this article works, in some small way, towards building a contemporary understanding of how school science can include two equally valid knowledge systems. Moreover, by operating in the middle-ground, and by employing Mutual Cultural Responsivity as a guide, new, authentic and meaningful knowledge system can emerge.

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Connective statement

Paper 4 entitled *Enacting the middle-ground: An approach using Indigenous sky stories*, uses the hierarchical Mutual Cultural Responsivity framework as a guide to progress the discussion on cross-cultural, science education. The paper provides critical understandings to show how the framework could move practitioners from a capacity model of cultural competency, to a response model. That is to say, practitioners operating in the middle ground between Indigenous and Western knowledge systems, are provided with a model that allows for their accumulated cultural training, and experiences, to generate educated responses in terms of services or delivered outcomes. Qualitative data from the Sky Stories school science program is used as a way to demonstrate how the three tiers of Mutual Cultural Responsivity (Awareness, Becoming, and Being) can operate in the cross-cultural, science education domain. The paper showed that authentic and meaningful, culturally appropriate science-educational research, teaching and learning is possible when the wants and needs of the school community are given priority over academic and institutional objectives.

Thus far, the use of qualitative data describing affective outcomes generated from the Sky Stories program, has largely dominated the thesis. An opportunity exists to show findings generated from a sample of quantitative data collected from two schools. With varying degrees of participation, pre- and post-occasion instruments were provided to students to elicit patterns of responses related to their perceptions of science in general, in school and in the classroom. In addition, students' responses to some of the experiences relating to the Sky Stories program are included. Chapter 6 provides an analyses and discussion of these data in an attempt to help highlight and further investigate the impact of the Sky Stories program.

Chapter 6: Students' perceptions of science and experiences during the Sky Stories program

Introduction

This chapter presents the results of the Middle School Science Questionnaire (MSSQ). The MSSQ was employed to help illuminate and further investigate the effectiveness of the Sky Stories program. The MSSQ collects information on student perceptions of science and their science classes. The researcher requested that participating students be surveyed both before and after the implementation of the Sky Stories program. Participation was purely voluntary. The pre- and post-occasion instruments were administered during science lessons.

While the instruments were provided to all 30 schools participating in the Sky Stories program, some teachers chose not to administer them or, as in most cases, supplied the researcher with incomplete sets. Teachers commented that administering the instruments was problematic in terms of fitting the task into a crowded timetable, and/or low student literacy skills. This resulted in teachers allowing for the non-completion of questionnaires by many students. There was also evidence of pattern marking. More specifically, some students who were perhaps troubled by the survey were instructed, or individually chose, to tick the first box for each item. This situation resulted in many surveys being void of any useful data. It is also noted that out of the total of 30 schools, only one primary school and one high school returned the matching sets described above. That is to say, it was possible to match only 233 of the questionnaires from the pre- to the post-occasion. The balance of the 521 returned questionnaires were either only on the pre- or the post-occasion but not on both.

For illustrative purposes, a more targeted analysis of one primary and one high school who provided matched pre and post data is presented in this Chapter. These two schools were considered to be ideal for analyses because:

- Each school contributed matching data sets from more than one classroom;
- The principal and staff whole-heartedly supported the implementation of the program;
- Teachers were organised into a specialised team;
- All teachers attended professional learning sessions;
- Individual teachers attempted to teach programs related Western Science concepts;
- Elders introduced cultural stories to the students; and,
- The teaching team organised a community night observation event involving cultural sky stories and night-sky observations using telescopes.

Site I - Context

The primary school is located in a rural town on Wiradjuri country in Central Western NSW. The school's Index of Community Socio-Educational advantage (ICSEA) of 923 is below the average national ICSEA of 1000. The school population of 430 students has an Indigenous student enrolment of 19% (ACARA, 2019). The local Wiradjuri community is well represented in the school. Except for science, various arts and literacy programs were either in place or had been trialled before the Sky Stories program was adopted. The school has two Wiradjuri support staff who work alongside students and teachers. A senior Wiradjuri Elder was known to staff and was a regular visitor. Generally speaking, the school maintains a positive, proactive relationship with the local community. The school has a good ongoing relationship with the University. The staff at Site I consisted of one teacher who taught a composite Year 5 and 6 class, two teachers who taught Year 5 students, and one teacher who taught Year 6 students.

Site II - Context

Site II is a secondary college located in Biripi Country (North Eastern NSW). The school has a school ICSEA of 943. The school population of 500 students has an Indigenous student enrolment of 12% (ACARA, 2019). The staff at Site II consisted of three teachers who taught Year 7 students and three teachers who taught Year 8 students, two teachers who taught Year 5 students, and one teacher who taught Year 6 students. At the beginning of the Sky Stories program, the researcher was told that relationships with the local community were strained. Teachers appeared frustrated that in the past, local Biripi groups did not appear to be interested in working with the school. Further investigation revealed that the demand for traditional knowledge by the school within short timeframes had caused Biripi Elders to temporarily withdraw and adopt a *wait and see* approach. Collaborative efforts between the teaching team and the university enabled a fresh approach to be established, which resulted in improved interactions between both parties.

Site I & Site II

Commonalities between the two teaching teams at the two sites were that all supervisors and teachers were non-Indigenous, all possessed at least some cultural discomfort, and while enthusiastic, all, except for one teacher at Site II, had limited knowledge of astronomy. At Site I, the regular primary class teachers taught science. At Site II, all teachers were experienced in teaching science. Table 1 shows the number of classes, teachers and students included in the analyses.

Table 1: School sites

Case study schools	Classes and (Teachers)	Total students
Site I – Regional primary school Years 5-6	4 (4)	150
Site II – Regional secondary college Years 7-8	6 (6)	83

Descriptions, coding and analyses procedures

The Middle School Science Questionnaire (MSSQ) was used to elicit students' perceptions about what happens in their science classroom and the way in which they interacted with the subject generally both outside of, and at, school. The MSSQ for students (Appendices J–K) was adapted from the Primary School Science Questionnaire (Goodrum, Hackling & Rennie, 2001). Minor adaptations of the Primary School Science Questionnaire included regrouping the items to address themes such as how the teacher provided contexts for science both before and during the Sky Stories program implementation, the teacher's behaviour in terms of feedback provided, and the way in which science activities were organised in the class. In the present study, the MSSQ for students contains 22 items for the pre-occasion, and 28 items in the post-occasion instrument. The six additional items in the post-occasion instrument specifically address students' experiences relating to Sky Stories program activities. Responses to all items were recorded using five-point scales (e.g., from *1=Never* to *5=Nearly every lesson).* The 22 items are organised into four themes which are:

- Students' experiences in school science
- Students' thoughts about school science
- Enjoyment of science in general, at school or in this class
- Students' experiences relating to Sky Stories program activities

The instrument was administered by participating teachers during science lessons before the program started and immediately after it had finished. The time of post testing depended solely on the rate at which teachers had completed the curriculum materials they had chosen to implement. Once the surveys were completed, the research team was notified to arrange the return of the instruments for coding, data entry and analysis. The researcher assigned student case numbers to each of the pre occasion MSSQs and matched these with corresponding post-occasion instruments to produce a matched data set using SPSS v24. All data have been aggregated and de-identified to protect the confidentiality of students and teachers. The names of the two school sites have been replaced with pseudonyms in the results presented below.

Results

As outlined earlier, sources of data were collected from students in one NSW primary (Site I) and one NSW high school (Site II). Comparisons of the MSSQ pre- and post-questionnaire patterns of responses are reported to determine the extent to which there is a difference from the pre- and the post-occasion. That is to say, a non-parametric Chi-Square test is employed to determine whether the patterns of responses obtained on the post-occasion is independent of the pattern on the pre-occasion.

To reduce the likelihood of a Type I error given that 22 items are being compared with the univariate analysis adopted, a full Bonferroni correction is employed. More specifically, the generally accepted p-value of 0.05 is substituted by the more rigorous p-value of 0.0023 (i.e., 0.05/22). Suitably protected, the analyses present the patterns of responses from each of the two sites separately within each theme. At the end of the results for each site, an additional frequency table is included to illustrate the reactions of students to the six post occasion only questions specifically relating to the Sky Stories program content. In these items, students recorded their responses using a 5-point scale (e.g., from 1 = *Never* to 5 = *Nearly every lesson*).

The results are organised around the four themes listed above. In each section of the results, the primary school results are presented first, followed by those for the high school. Some commentary is offered on any differences and discussion of these is taken up more fully in the final section of this Chapter.

Theme 1: Students' experiences in school science lessons

Table 2 presents the percentage of responses to items concerning students' experiences in school science at the primary school designated as Site I. The results show there is no significant difference in the patterns of responses from the pre- to the post-occasion. It would appear that students at Site I were already experiencing similar teaching approaches both prior to, and during, the Sky Stories program. Most of the students had experienced opportunities to work out explanations by themselves or with their friends in group-work arrangements. Table 2 also shows that prior to, and during, the Sky Stories program, students were familiar with finding information online while at school.

Table 2: Site I – Students' experiences in school science lessons

Item	Occasion	Never	Rarely	Occasionally	Most of the time	Nearly every lesson	*p*
I copy notes the teacher gives me	Pre	4.7	8.7	24.7	30.7	31.3	0.8235
	Post	5.3	12.0	24.7	27.3	30.7	
I work out explanations in science on my own	Pre	2.0	11.3	42.7	37.3	6.7	0.2906
	Post	3.3	12.0	46.0	28.0	10.0	
I work out explanations in science with friends	Pre	3.3	4.7	36.7	40.7	14.7	0.0387
	Post	6.7	11.3	38.7	30.0	12.0	
I have opportunities to explain my ideas	Pre	4.0	11.3	38.0	29.3	16.7	0.3693
	Post	0.7	8.0	14.7	31.3	28.0	
We have class discussions	Pre	3.3	3.3	20.7	40.0	30.7	0.0067
	Post	2.7	8.0	32.7	26.7	28.0	
We learn about scientists and what they do	Pre	14.7	33.3	34.0	12.7	5.3	0.0179
	Post	15.3	20.0	39.3	19.3	6.0	
We do our work in groups	Pre	4.0	8.0	42.0	32.0	14.0	0.3562
	Post	5.3	14.7	36.7	29.3	14.0	
Look for information on the Internet at school	Pre	11.3	22.7	42.0	19.3	4.7	0.0801
	Post	5.3	22.0	42.0	24.0	6.7	
Investigate to see if our ideas are right	Pre	5.3	18.0	30.0	37.3	9.3	0.5336
	Post	5.3	16.7	38.0	31.3	8.0	

Bonferroni corrected p-values: *= $p < 0.0023$, ** $p < 0.00045$, *** $p < 0.000045$

Table 3 shows the percentage of responses to nine items concerning the experiences Site II high school students' have in school science lessons. Results show that while the majority of responses indicate students had already experienced teaching approaches similar to the methods practiced and/or suggested during the Sky Stories program, two items show significant differences.

Table 3: Site II – Students' experiences in school science lessons

Item	Occasion	Never	Rarely	Occasionally	Most of the time	Nearly every lesson	*p*
I copy notes the teacher gives me	Pre	2.4	2.4	16.9	31.3	47.0	0.7036
	Post	1.2	2.4	20.5	32.5	43.4	
I work out explanations in science on my own	Pre	1.2	6.0	48.2	36.1	8.4	0.0223
	Post	3.7	14.6	37.8	31.7	12.2	
I work out explanations in science with friends	Pre	3.6	3.6	30.1	41.0	21.7	0.0915
	Post	8.5	6.1	35.4	31.7	18.3	
I have opportunities to explain my ideas	Pre	3.7	13.4	36.6	32.9	13.4	0.0926
	Post	11.0	17.1	32.9	26.8	11.0	
We have class discussions	Pre	2.5	3.8	18.8	38.8	36.3	0.00060954*
	Post	3.8	11.3	31.3	30.0	23.8	
We learn about scientists and what they do	Pre	9.6	20.5	39.8	20.5	9.6	0.9058
	Post	8.4	18.1	43.4	21.7	8.4	
We do our work in groups	Pre	4.8	9.6	43.4	33.7	8.4	0.0088
	Post	7.2	18.1	39.8	21.7	13.3	
Look for information on the Internet at school	Pre	13.3	24.1	44.6	16.9	1.2	0.00095463*
	Post	4.8	22.9	47.0	20.5	4.8	
Investigate to see if our ideas are right	Pre	7.2	21.7	36.1	28.9	6.0	0.5984
	Post	4.9	18.3	42.7	28.0	6.1	

Bonferroni corrected p-values: *= p < 0.0023, ** p < 0.00045, *** p < 0.000045

Closer inspection of these data relating to engaging in 'Class discussions' shows that on the pre-occasion, *Most of the time* and *Nearly every lesson* responses totalled 75.1% whereas in the same scales for the post-occasion, responses total 53.8%. Further inspection of the item shows that the *Occasionally* difference increased from 18% on the pre-occasion to 31.3% on the post-occasion. These data suggest that Site II students appear to have had *less* opportunity for 'Class discussion' during the implementation of the Sky Stories program in high school.

There is also a significant difference in the pattern of responses from the pre- to the post-occasion of testing for the item related to 'Look for information on the Internet'. Inspection of the *Occasionally* to *Nearly every lesson* responses show a 62.7% response on the pre-occasion while on the post-occasion, a result of 72.3% is seen. That is to say, the high school students seem to be reporting that they were provided with more opportunities to use the internet to find information.

While the primary students' patterns of responses were not significant, the results suggest a similar pattern to that of the high school students. In both Sites I and II, students were involved in less 'Class discussion' and more 'Internet' usage. One possible explanation may be that instead of discussing aspects of cross-cultural astronomy, students were engaged with a more hands-on 'doing' approach.

Theme 2: Students' thoughts about school science

Table 4 shows the percentage of responses to 10 items concerning what Site I students thought about school science on both the pre- and post-occasions. There are four significant differences in the pattern of responses from the pre- to the post-occasion of testing.

There were 43% of students who were *Almost never* to *Sometimes* 'Curious' on the pre-occasion, compared with 16.7% on the post-occasion. It can also be seen that students had increased their *Almost always* boredom rate from 9.3% to 18.7%. Conversely, 15.3% of students responded by saying they were *Very often* 'Bored' during school science class on the pre-occasion whereas only 9.3% were *Very often* ‘Bored’ on the post occasion.

Table 4: Site I – Students’ thoughts about school science

Item	Occasion	Almost never	Sometimes	Often	Very often	Almost always	*p*
I get excited about what we do	Pre	18.7	36.0	30.0	6.7	8.7	0.1376
	Post	22.0	40.7	26.7	6.7	4.0	
We have enough time to think about what we are doing	Pre	5.3	26.0	37.3	20.0	11.3	0.4426
	Post	6.7	28.7	36.7	20.7	6.7	
I am curious about the science we do	Pre	12.8	30.2	21.5	22.1	13.4	7.24E-48 ***
	Post	0.7	16.0	28.0	32.0	15.3	
I am bored	Pre	23.3	37.3	14.7	15.3	9.3	0.00104*
	Post	12.7	43.3	16.0	9.3	18.7	
I don’t understand the science we do	Pre	22.7	58.7	11.3	4.7	2.7	0.2109
	Post	29.3	48.0	16.0	3.3	2.7	
I find science & technology too easy	Pre	17.3	47.3	24.7	3.3	5.3	0.7786
	Post	18.0	46.0	26.0	6.0	4.0	
I find science challenging	Pre	12.7	49.3	24.0	10.7	2.7	0.3140
	Post	15.3	47.3	24.7	6.7	6.0	
I think science is too hard	Pre	50.0	36.7	12.7	0	0.7	0.2815
	Post	45.3	34.7	14.7	2.7	2.7	
Think and ask questions	Pre	4.0	12.0	43.3	26.0	14.7	1.81E-06 ***
	Post	0.7	8.0	26.0	35.3	18.0	
Understand and explain science ideas	Pre	2.7	18.7	38.7	25.3	14.0	0.000153 **
	Post	11.3	23.3	42.0	12.7	9.3	

Bonferroni corrected p-values: *= p < 0.0023, ** p < 0.00045, *** p < 0.000045

Students’ patterns of responses between the pre- and post-occasion of testing are significant when asked how much they had to ‘Think and Ask Questions’ during school science class. For example, in the *Very often* column, it can be seen that there is a 9.3% increase in the *Very often* response from the pre- to the post-occasion data. The *Almost Always* column also shows an increase (3.3%) in the frequency.

It can also be seen that while 21.4% of students’ thought they had *Almost never* to *Sometimes* opportunities to ‘Understand and Explain Science’ ideas in-class in the pre-occasion, a shift to 34.6% of students in the same category is noted in the post occasion survey. It would appear that the primary-school students had fewer opportunities to understand and explain their ideas during the implementation of the Sky Stories program compared with their previous experiences in school science.

Table 5 presents the percentage of responses to 10 items related to the high school students' thoughts about science at school at Site II students have about school science. Results show five items are highly significant in terms of differences in the pattern of responses from the pre- to the post-occasion of testing with changes occurring largely in the mid-range. Table 5 shows that students said that they were *Sometimes* curious (31.3%) in their post-occasion responses. In the *Often* 'Curious' response scale, there is a change in the pattern of responses from 13.4% to 30.1%.

While significant, the differences in the patterns of responses in the 'I am bored' item vary. It can be seen that in the *Often* category there is a 1.3% increase from the pre- to the post-occasion whereas in the *Very often* category there is a 6% reduction. The pattern of responses from students to the statement that they found science 'Challenging', while significant, is difficult to disentangle. That is to say, the response pattern changed from 10.8% to 19.3% for *Almost never* and 3.6% to 7.2% for *Almost always*. One might conclude that the Sky Stories program had a differential impact on the degree of challenge faced by the students and reacted in a variety of ways.

The 'Think and ask questions' item shows a highly significant change in the pattern of responses that required them to do these things more often. An interrogation of this item shows that the middle range scale of *Often* is different across the occasions with 45.8% of responses in the pre-occasion and 25.3% on the post occasion. The pre-occasion *Very often* and *Almost always* responses in this item total 42.2% whereas the post-occasion responses total 54.2%. These data suggest that students are being asked to think and ask questions more often during the Sky Stories program.

Table 5: Site II – Students' thoughts about school science

Item	Occasion	Almost never	Some times	Often	Very often	Almost always	*p*
I get excited about what we do	Pre	22.9	34.9	26.5	8.4	7.2	0.0621
	Post	31.3	38.6	20.5	6.0	3.6	
We have enough time to think about what we are doing	Pre	4.8	28.9	41.0	16.9	8.4	0.0075
	Post	11.0	35.4	39.0	11.0	3.7	
I am curious about the science we do	Pre	12.2	32.9	13.4	26.8	14.6	2.884E-09 ***
	Post	19.3	31.3	30.1	13.3	4.8	
I am bored	Pre	22.9	32.5	15.7	18.1	10.8	1.6668E-09 ***
	Post	10.8	39.8	20.5	6.0	22.9	
I don't understand the science we do	Pre	20.5	55.4	12.0	8.4	3.6	0.0747
	Post	30.1	45.8	14.5	4.8	4.8	
I find science too easy	Pre	18.5	42.0	27.2	4.9	7.4	0.6462
	Post	15.7	47.0	24.1	7.2	6.0	
I find science challenging	Pre	10.8	53.0	21.7	10.8	3.6	2.1903E-07 ***
	Post	19.3	45.8	25.3	2.4	7.2	
I think science is too hard	Pre	45.8	38.6	14.5	0	1.2	0.2687
	Post	43.4	33.7	16.9	2.4	3.6	
Think and ask questions	Pre	3.6	8.4	45.8	27.7	14.5	4.348E-05 ***
	Post	1.2	12.0	25.3	33.7	20.5	
Understand and explain science ideas	Pre	1.2	19.5	36.6	26.8	15.9	3.9706E-09 ***
	Post	11.0	25.6	45.1	12.2	6.1	

Bonferroni corrected p-values: *= p < 0.0023, ** p < 0.00045, *** p < 0.000045

Table 5 results also show a significant difference in the pattern of responses between the pre- and post-occasion of testing on whether students 'Understand and explain science ideas'. The table shows that while 1.2% of students answered *Almost never* on the pre-occasion response, the post-occasion response shows 11%. At the other end of the Likert-scale, 15.9% of students responded that they *Almost always* got to 'Understand and explain their science ideas' on the pre-occasion whereas only 6.1% responded in this way on the post-occasion. The middle range scale of *Often* contains the bulk of students' pattern of responses. Here, there is an increase in the frequency of responses from 36.6% in the pre-occasion to 45.1% in the post-occasion of testing.

Comparisons between Site I and Site II show that both primary and high school students were often more ‘Curious’ but more ‘Bored’ in their science lessons. Similarly, students from both sites got to think and ask questions in class. On whether students had opportunities to understand and explain their ideas during the implementation of the Sky Stories program, these data suggest that compared to their previous experiences, primary-school students had fewer opportunities whereas high school students were provided with more.

Theme 3: Enjoyment of science in general, at school or in this class

Table 6 shows the overall percentage of responses to the three items concerning the primary students’ ‘Enjoyment’ of science at Site I. The results show that there are no significant differences in the students’ patterns of responses from the pre- to post-occasion of testing. Closer inspection of these data suggests that students do not appear to have dramatically changed their position from the pre- to the post-occasions.

Table 6: Site I – Enjoyment of science in general, at school or in this class

Item	Occasion	Strongly disagree	Disagree	Sometimes	Agree	Strongly agree	*p*
I enjoy science & technology in general	Pre	5.3	10.7	34.7	32.0	16.7	0.0220
	Post	13.3	6.0	39.3	28.0	12	
I enjoy the science & technology we do at this school	Pre	6.0	13.3	38.0	30.7	11.3	0.3660
	Post	12.0	11.3	34.0	32.0	9.3	
I enjoy the science & technology we do in this class	Pre	5.3	14.0	36.0	30.7	13.3	0.0108
	Post	14.7	9.3	40.7	21.3	12.7	

Bonferroni corrected p-values: *= $p < 0.0023$, ** $p < 0.00045$, *** $p < 0.000045$

Table 7 shows the overall patterns of responses to three items concerning the high school students’ ‘Enjoyment’ of science at Site II. There are two significant differences in the patterns of responses from the pre- to the post-occasion of testing. While the

Sometimes scale in each of the three items suggests a positive change, larger differences in the students' patterns of responses are seen in the peripheral scales.

Table 7: Site II – Enjoyment of science in general, at school or in this class-all classes

Item	Occasion	Strongly disagree	Disagree	Sometimes	Agree	Strongly agree	*p*
I enjoy science & technology in general	Pre	4.8	14.5	37.3	24.1	19.3	1.05922E-08 ***
	Post	17.1	3.7	40.2	24.4	14.6	
I enjoy the science & technology we do at this school	Pre	6.0	13.3	39.8	27.7	13.3	0.1410275
	Post	14.6	11.0	40.2	23.2	11.0	
I enjoy the science & technology we do in this class	Pre	3.6	14.5	41.0	27.7	13.3	0.00021442 **
	Post	17.1	9.8	42.7	15.9	14.6	

Bonferroni corrected p-values: *= $p < 0.0023$, ** $p < 0.00045$, *** $p < 0.000045$

A significant proportion of students (from 4.8% to 17.1%) *Strongly disagreed* that they 'Enjoyed science in general'. While not significant, a proportion of students (from 6.0% to 14.6%) *Strongly disagreed* that they 'Enjoyed the science they do at school'. For the remaining item about the 'Science they do in class', there is a significant change in the patterns of students' responses that indicates that they did not enjoy the science involved in the Sky Stories program. There is a reduction in the *Agree* and *Strongly agree* categories from 41% to 30.5% and an increase in the *Strongly disagree* and *Disagree* categories from 18.1 to 26.9%.

While primary school students do not appear to have changed their position on any of the items from the pre- to the post-occasions, high school students have changed their position in the areas of enjoyment in science generally, and in class but not at the school. This begs the question why? Perhaps this could be interpreted as resistance to the occasions of testing due to students having to complete the survey.

Theme 4: Students' experiences relating to sky stories program activities

Figure 1 shows responses to some key Sky Stories program-related activities that may have been experienced by the primary school students. The data are presented as a stacked bar graph showing the frequency of activities from *Never to 6+ days*.

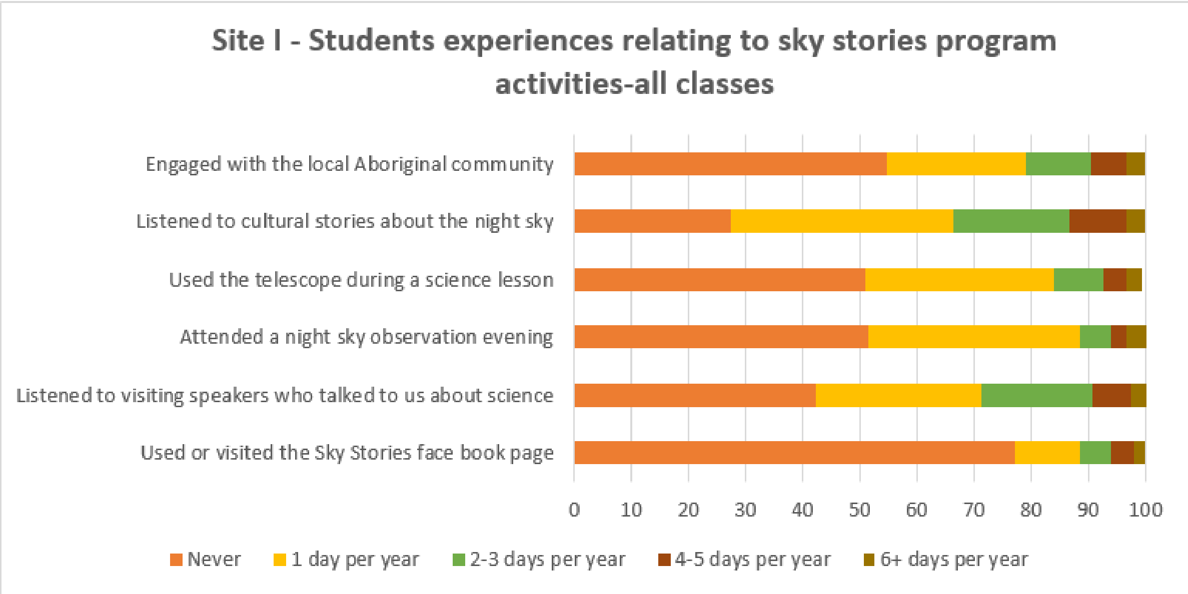

Figure 1: Site I – Students' experiences relating to sky stories program activities

Engagement with the local Aboriginal community was a key component of the Sky Stories program. Figure 1 shows that 54.7% of students said they had no engagement whereas 45.3% said they had. This is intriguing as the Site I primary school provided multiple opportunities for engagement with members of the local community, particularly at the night sky observation evening. The figure shows that 62% of students said that they had listened to cultural stories about the night sky between one and 6+ days during the program while 27% said they had not.

The results also show that 48.7% students attended their school night sky observation evening indicating that these students may have experienced contact with their local Aboriginal community outside of class time. Figure 1 also shows that over 96% of students used their school telescope during the program. It can also be seen that the majority of students did not visit or use the Sky Stories Facebook page. An analyses of Facebook usage is presented in the following Chapter.

Figure 2 shows High school students' responses to the Sky Stories program related activities that may have been experienced at Site II. The results show that 57.8% of students were present when visiting speakers talked to them about science and/or sky stories. It can also be seen that a relatively large proportion of the students did not attend the night sky observation event organised by their school. Figure 2 shows that the majority of students used their school telescope at least 1 day per year. Figure 2 also appears to show that the majority of students (71.1%) said they had listened to cultural stories about the night sky.

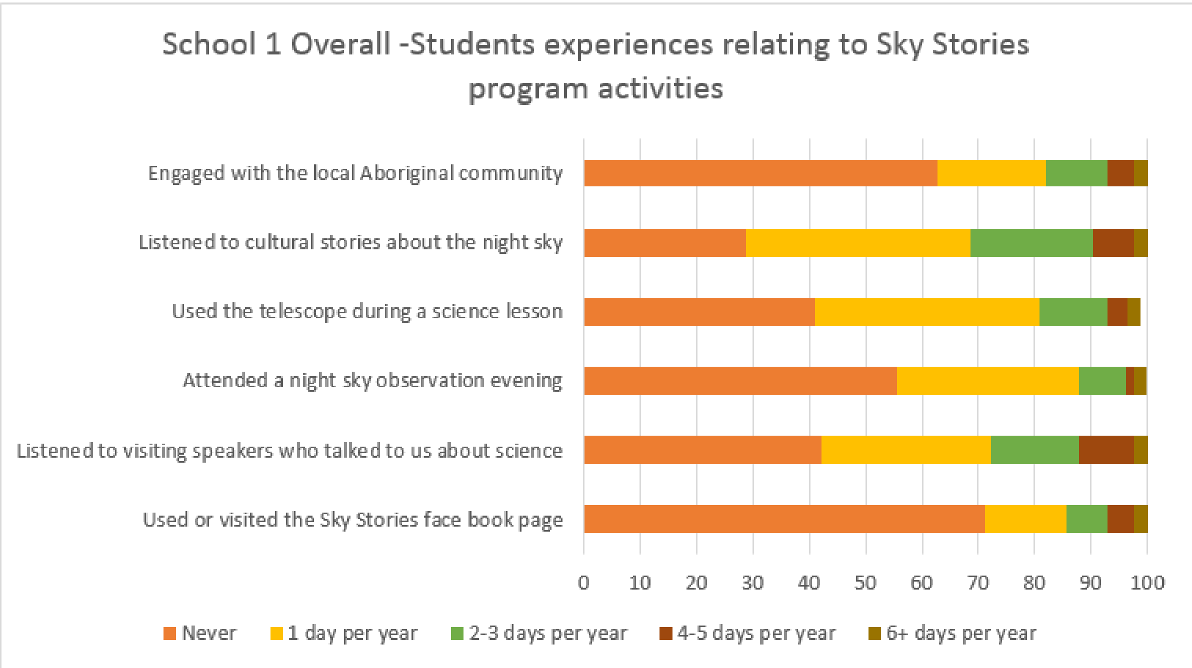

Figure 2: Site II – Students' experiences relating to sky stories program activities

Discussion and conclusions

Patterns of responses, organised into four themes, were provided by students from one primary school (Site I) and one high school (Site II). In one theme, there were four significant items that were common between Site I and Site II. More specifically, significant changes in the pattern of responses between the pre- and post-occasion were present in four identical items related to students' thoughts about school science at both Site I and Site II.

Differences in primary school student responses suggested that they were now less curious about science while differences in high school student responses appear to suggest they were significantly more curious. A possible explanation for the contrasting results may be due to different teaching styles, the differing content matter, and the different confidence levels of primary and high school teachers. More primary and secondary students responded that they were bored during the Sky Stories program. One possible explanation for these results may be due to student resistance to the new ideas and approaches contained in the Sky Stories program. That is to say, the students were now being asked to work in a different way compared to the one that they had grown accustomed with their teacher.

Another response pattern that was common to both primary and high school students was in relation to the item on whether they get to *Think and ask questions* during science lessons. Both of these datasets showed a significant positive change in their patterns of responses. That is to say, students perceived they had more opportunities to *Think and ask questions* in their science classroom. One possible explanation for these matching results may be that teachers responded to the pedagogical suggestions that were delivered during the Sky Stories professional development training day (as discussed in Chapter 4).

When asked if they understood and explained science ideas, primary and high school students' responses showed a significant but negative difference from the pre- to the post-occasion. It would appear that the primary and high school students had fewer opportunities to understand and explain their ideas during the implementation of the Sky Stories program compared with their previous experiences in school science. It is possible primary school students lacked the presentation skills that are accumulated through experience. Another possible explanation could be that primary and high school teachers did not allow for the extra time or methods needed for students to absorb and present their understandings.

Five additional significant changes in patterns of responses across the themes of student experiences and thoughts were provided from Site II high school students. *Class discussions* responses, while significant in terms of percentile differences, were varied. Similarly, significant changes in patterns of responses showing whether secondary students found science *Challenging* was also varied.

One possible explanation for the relationship between the varying results could be that teachers introduced new content in different ways, which in part, confused or caused an imbalance in student expectations. Another possible explanation may be that teachers were not confident in delivering the new content and approaches of the Sky Stories program and may have reverted to didactic approaches. Teachers were asked to leave the comfort zone of normal science and include content and cultural competency practices that may have been unfamiliar and/or unsettling to them (as discussed in Chapter 4 & Chapter 5). Given they had only one full day of professional development, it is unsurprising some varying responses were offered by their students.

While primary school students did not significantly change their position on any of the three *Enjoyment* items, high school students returned two significant results relating to not enjoying science in *general*, and in the *classroom*. Enjoying science *at school* was not a significant item. One possible explanation for this may be that high school students resented the pre-and post-occasion testing and responded to the two items as a protest.

The questionnaire results suggest that at the two school sites the Sky Stories program turned students off to a certain extent but, at the same time, there are tangible positives that can be interpreted from the data. The significant differences in patterns of responses from the pre- to the post-occasion of testing indicates that teachers may have changed their pedagogical approaches. Students may not have liked these but it appears they were more active and involved in science. The data shows that during the Sky Stories program, the majority of primary and secondary students used their school telescope to view objects in the sky. This may indicate a positive interest in astronomy and/or, a positive interest in hands-on activities. This aspect of the research is analysed further in Chapter 7. Similarly, a large proportion of students said they had listened to cultural stories about the night sky indicating teachers did, in fact, embrace the cultural elements of the program. A caveat placed on this finding, however, is that most student responses showed they had not engaged with their local community. It is possible that teachers chose to use the cultural resources provided by the Sky Stories research team instead of having Aboriginal knowledge holders tell their sky stories. Another explanation is that a proportion of students chose not to attend their night sky community event and as a result missed hearing cultural sky stories presented by Elders or Aboriginal knowledge holders. While it is beyond the scope of this research, it would be interesting to see the extent of change in student perceptions of science if the program was offered in an extended timeframe.

References

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Connective statement

Chapter 6 draws data from one participating primary school and one participating high school to analyse and discuss students' perceptions of science and their experiences with the Sky Stories program. Patterns of responses between pre- and post-occasion questionnaires, organised into three themes, were presented to show students' experiences, thoughts and enjoyment of science. A fourth theme was presented showing students' responses to their experiences during the Sky Stories program. The results showed both positive and negative outcomes from the program. Explanations were offered to unpack or disentangle the sometimes varying results. Regardless, some highly significant results were shown. Implications from the research include the need to increase opportunities for teacher professional development in areas of pedagogical content knowledge and cultural competency.

The fifth and final paper, entitled: *Beyond the middle school science classroom: Using social media to connect the Indigenous Sky Stories community,* provides evidence of participant engagement and collaboration during the Sky Stories program. Used to deliver content, act as a community notice board, and a means to collect research data, a dedicated Sky Stories Facebook page was used to trial new ways in which teaching and learning can be delivered and evidenced. The paper also highlights the platform's ability to promote positive social capital amongst individuals, families, the school and the wider community.

Chapter 7: Paper 5

Evidence of submission

Paper 5 – Beyond the middle school science classroom: Using social media to connect the Indigenous Sky Stories community. Paper 5 was submitted to the Australian Science Teachers Associations primary publication: Teaching Science. The paper was received by the editors on 14 February 2019 and accepted for publication, subject to minor edits on 13 March 2019 (Appendix Q).

Beyond the middle school science classroom: Using social media to connect the Indigenous Sky Stories community

Nicholas Ruddell

This paper examines the use of social media as a collaborative and engagement tool for participants in a middle school science research project conducted over a three-year period. Sky Stories is a learning initiative that employs a blend of Indigenous and Western knowledge of astronomy to engage Year 5–8 middle school students in investigative science. An integral element of the Sky Stories Project is acknowledging links amongst individuals, families, and the school community and their sky stories. This enables new ways of learning, teaching and community engagement built around science and astronomy while employing culturally embedded, non-transmissive pedagogies. The Sky Stories program goals include providing opportunities for localising 'stories' in school communities, expanding teacher cultural content knowledge, and developing teachers' competence and confidence. Social media in the form of a Facebook page was used as an interactive notice board and also as a content sharing tool for school executives, teachers, and the research team. Evidence from Sky Stories participants is examined and discussed to illuminate the use of social media as a tool for showing engagement and participation. In this study, engagement is defined as the activity of interacting with local and broader communities using the Sky Stories Facebook page and/or, being *digitally evidenced* as actively interacting with the Sky Stories program activities.

Given the incredible growth of communication in the 21st century, social media platforms would appear to be an ideal tool to assist schools reach and communicate with a wider audience. The literature that concerns itself with social media in education is still emerging. Earlier research (Yang, Wang, Woo, & Quek, 2011) was critical of the medium and mainly concerned with students' and teachers' engagement with social networking sites while Selwyn (2009) questioned the value of social media as a learning environment. Ellison, Steinfield, & Lampe (2011) suggested social media is simply an instrument that supports pre-existing social relationships and does little to expand social capital. Two interesting points of view are represented in this early literature. Madge, Meek, Wellens, and Hooley (2009) suggested that students viewed the use of social media in education as an intrusion into their own personal social space. In contrast, Hung, & Yuen (2009) emphasised the potential of social media to promote learning, develop networks and share resources.

More recently, educational research explores the likelihood of students successfully operating in the social media domain in terms of developing critical skills, and receiving additional support. For example, Swist, Collin, McCormack and Third (2015) argue for the promotion of mixed media literacies that include moral and ethical considerations, more peer and intergenerational support and more opportunities for young people to be involved in platform design. The issue of recreational versus critical usage in schools has yet to be resolved. Cia and Amann (2018) maintain that the transition from students' spontaneous usage to thoughtful, educative operations that promote conclusive learning outcomes is not possible without sustainable, long term collaborations between educational researchers and social media developers.

Moving beyond education but relevant to the community context of this study, Carlson and Fraser (2018) offer a comprehensive review of social media usage by Indigenous Australians. Surveying and interviewing Indigenous Australians across the continent, the authors concluded that social media helped respondents express their Indigeneity and gave them a strong sense of belonging to community. While contentious (Rennie, Hogan & Holcombe-James, 2016) due to the presence of family feuds and racism, it appears that social media offers a positive method of maintaining and renewing familial systems within Indigenous communities previously isolated from traditional kinship and Western social constructs.

Understanding the home worlds of students and establishing strong community relationships appears to be critical for the success of culturally embedded curriculum design (Oscar & Anderson, 2009). The attendance and participation of parents and the community has, in part, been shown to contribute to the success of student learning outcomes (Harrison & Greenfield, 2011; Oscar & Anderson, 2009). In the context of an indigenised curriculum, student engagement can be strengthened by using hands-on, locally sourced language, knowledge and practices informed by developing strong collaborative relationships with the Indigenous community (Mack, et al., 2012). Nonetheless, the engagement of Indigenous parents is difficult and can be problematic. A possible solution, explored in this paper, may be the use of social media. The purpose of this article is to explore how a social media platform was used to both engage, and show the engagement of, school professionals, Indigenous and non-Indigenous students, their parents and the community in school science.

Context for this research

The Sky Stories program was a school science initiative designed to engage teachers, Indigenous and non-Indigenous students, their parents and their community over one school term. This article discusses how a collaborative team of school executives, teachers, Aboriginal support officers, university staff, researchers and supporting professionals engaged themselves and the broader school community audience using a dedicated Facebook page.

The Sky Stories program employed a blend of Western and Indigenous knowledge systems to connect Years 5–8 science students to astronomy content in the Australian Science Curriculum. Integral to the program is the inclusion of each school's local community. Along with daytime activities such as investigation, model making, online learning and cultural story-telling, each school was encouraged to offer a community night sky observation event involving a barbeque, interpretive cultural performances, story-telling and the use of telescopes supplied to the school. Two Units of Work (UoWs), one for primary and one for high school, were provided to 30 NSW schools participating in the program that ran for two consecutive years. As part of the teaching and learning package, a 20 cm Dobsonian telescope was donated to each participating school. Each telescope included three eyepieces, a solar filter and a flat-packed swivel base that students had to build under the supervision of their teacher.

In order to keep all participants informed, foster between-school collaboration, and to build community links, a Facebook page was set up and managed by a Sky Stories Program (SSP) team comprised of university personal, university researchers, and a social media professional. The SSP team consulted a Wiradjuri Elder on all matters relating to cultural practices and protocols.

Organised into area clusters, school executives, teachers and Aboriginal Education Officers (AEOs) attended a professional development (PD) session lasting one full day. The schedule included an overview of Aboriginal astronomy, the UoWs and associated resources, and an introduction to social media usage. Before the PD sessions were organised, school staff said that inappropriate content and the lack of training was a major impediment to using social media in schools. Language and anti-troll security were also serious areas of concern. As a consequence, an independent social media professional was engaged by the SSP team to train school executives and teachers.

Ongoing support was provided to participants via an area coordinator from the university, social media, telephone and email. An example of social media support included posting videos such as *How to build your telescope* and *How to organise a community night observation event* onto the Facebook site. In another example, area coordinators from the university added new teachers to the Facebook page and offered impromptu training via telephone and email. Table 1 provides an overview of resources provided to participating primary and high schools.

Table 1: Sky Stories resource overview

Target	Resources
Primary schools	6-lesson plan sheet Primary Connections *Earth's place in Space* module - Digital and hardcopy
High schools	16-lesson ideas sheet Science by Doing: Earth in Space teacher guides and Unit at a Glance booklet - Digital and hardcopy Science by Doing: Earth in Space Student activities, and guides - Digital and hardcopy
All participating schools	Authorised access to a dedicated Sky Stories Facebook page
All participating schools	Sky Stories Activity booklet – Night & day, The seasons, The moon, Stargazing and The solar system - Digital Sky Stories Indigenous Australian resources pack – select books, videos and website links - Digital The Murray Cod Story lesson plan - Digital The story of Wuriunpranalli the Sun woman - Digital Dust Echoes stories and study guides: MoonMan, Morning Star and Namorrodor - Digital and hardcopy(s).
All participating schools	Introduction to the Sky Stories project - Video Overview of Teaching & Learning resources - Video How to organise a community night sky observation event - Video How to build your telescope - Video How to set up and align your telescope - Video
All participating schools	1 x Dobsonian 20 cm telescope 1 x 8mm lens 1 x 12mm lens 1 x 15mm lens 1 x solar filter

Research

Informed consent for the collection of research data was obtained from all Sky Stories participants. Access to schools was negotiated with principals and teaching teams. During a period of three years, a variety of data were collected. For the purposes of this paper, Facebook page posting activity, digital images and observational data is used to highlight participant involvement. A master spreadsheet was used to code and store user and posting content type. For example, screen shots and frequency counts were taken from the Sky Stories Facebook book page. Images of students engaging with their telescopes or performances were obtained with permission, while on school sites. Due to the Sky Stories Facebook page being a closed community, all other potential contributors would have needed to seek permission to post and/or send their content to an authorised administrator.

Table 2: Social media contributors and their roles

Contributor	Role
School principals, assistant principals and teachers and AEOs	Posting content and sharing links
University based school coordinators	Administration, posting content, sharing links, modelling
Academics	Posting content, sharing links, modelling
University based Indigenous curriculum support team	Posting content, sharing links, modelling
An external social media professional	Training, mentoring, administration, posting content, sharing links, modelling

Table 2 shows five identified groups of contributors that had access to the Facebook page. In examining the content of the Facebook page, eight themes were used to help categorise the Posts:

1. Aboriginal astronomy;
2. International indigenous astronomy;
3. Event notifications;
4. General astronomy;
5. Sky Stories community events;
6. Sky Stories content (e.g., how to videos);
7. Teaching outcomes (e.g., student products); and
8. Teacher collaboration.

Findings

This section presents the findings of the research using a mixed method approach. Over a three-year period there were 259 posts on the Sky Stories Facebook page. The breakdown and analyses of these data is presented in two ways. First, an overview is provided to show frequency counts by groups. Second, group postings, organised into six themes, are provided to show evidence of engagement.

SSP Team contributions

The majority of posting activity (122 or 49.7%) was by the university Indigenous curriculum support team who were the designated content managers of the page. Content from this group comprised the sharing of general and cultural astronomy facts, links, stories and news. The data also shows that over the three-year period, content and regularity of postings from this team remained consistent.

In the same period, there were 49 (18.3%) posts from university coordinators. This group was responsible for supporting participating schools and managing the overall administration of the Facebook page. Posted items included “introductory” and “how to” videos, event notifications, general astronomy content and re-sharing of teacher posts.

The external social media professional was responsible for training and support, mentoring and modelling of Facebook posting activity during the Sky Stories program. Over the three-year period, the external social media trainer posted 29 times (10.8%). The content comprised of regular messaging about social media training, sharing teacher posts and commentary in support of teacher posts. University academics also had a presence with several posts in support of teacher enquiries about astronomy, sharing of links and news, and in two cases, the sharing of external university posts related to cultural sky stories. Posting data from professional development sessions is presented in the next section.

SSP professional development for teachers

Professional development for school principals, assistant principals, teachers and AEOs occurred one or two terms before the roll out of the Sky Stories program. Training in the use of Facebook was a priority as a large proportion of participating school staff were apprehensive at using the platform both personally and professionally. During the sessions, teachers were informed on Facebook usage and security. A framework for ongoing support was also provided. As mentioned, security was a priority for all participants of the Sky Stories program. In an effort to model posting and encourage teachers to take up the call to engage in social media related to the program, the social media trainer posted:

> "Discovery learning is the experience for most teachers attending today's Social Media training session. Some of the more mature members of the group reflected on a time when the only real time multimedia conversation was had using a phone that was attached to a cord in the wall. In stark contrast a younger teacher described conversations that use only emoticons & other symbols on mobile devices" (Social media trainer post).

Language protocols and administration training formed a large part of the professional development sessions. This lessened concerns and gave confidence to principals and teachers alike. Following a professional development session, one principal posted:

> "The participating in hands on activities and the professional look of the official branding have helped alleviate some of the staff concerns over using social media to encourage community support. The support of the AECG [Aboriginal Education and Community Group] is encouraging for the future success of this program …" (Principal 1 post)

Participants were asked to post comments to gain experience and confidence with the platform. For example, at one professional development session a teacher posted:

> "Really excited about being involved in the Indigenous Sky Stories [program] and getting our community involved with us through this Facebook page. Stage 3 staff and students [will be] learning about the Earth's place in space [a Primary Connections unit]. The community is also invited to join us at the conclusion of the unit for a night of sky viewing and story sharing. We welcome any Indigenous community members with stories to share about the stars, Moon and sky to joins and share these stories" (Teacher 3 post).

Teachers also used the opportunity to post images and comments related to them participating in the professional development sessions. For example, Figure 1 shows a post by an attending teacher who offers comments on the potential to build community involvement. Posting data from schools is presented in the next section.

Figure 1: Teacher 1 posting into the Sky Stories Facebook page

School contributions

It is noted that most activity from participating school principals, assistant principals and teachers and AEOs usually occurred within the confines of one school term per year when they implemented the unit. The exceptions were when teachers posted test content (as evidenced above in Figure 1) while attending the SSP professional development day. While 30 schools participated in the Sky Stories program 15 schools organised into over 30 classes, chose to engage with the Sky Stories Facebook page. In all cases, one teacher from each school was assigned the responsibility of posting their Sky Stories program content.

Frequency data collected from the Sky Stories Facebook page shows school principals, assistant principals, teachers and AEOs posted 59 (21.2 %) times over a three-year period. In some cases, this included dual posts on both the Sky Stories page, and the schools' own social media platforms and/or newsletters. Overall, this group posted content largely consisting of images, videos and commentary of students engaging in activities such as model making, building telescopes, and attending lessons and/or events such as cultural story-telling and online link ups with astronomers. This group also posted the majority of images and commentary about community night sky events that occurred in each of the participating schools (see Community engagement section below).

School executives and teachers sharing resources

Following their professional development session, school principals, assistant principals, teachers and AEOs used their training to continue posting images, comments and announcements for the duration of the program. Data in the form of Sky Stories Facebook content is used to highlight teaching staff engagement with the platform.

One of the aims of the Sky Stories program was to encourage inter-school collaboration. Throughout the three-year program, there was evidence of teachers sharing knowledge, ideas and resources. For example, along with some commentary on a lesson her students were engaging with, one teacher posted a video she found on YouTube directly relating to Eratosthenes and measuring the circumference of the Earth (Primary Connection: Earth's place in space; lesson 1).

This prompted other teachers to follow with a variety of resources including images of celestial objects and general knowledge of astronomy. For example, a participating teacher shared an interactive resource and commented;

> "Stage 3 students explored how the Moon moves around the Earth and how the Earth moves around the Sun. The students used an interactive online program to see a visualisation of this process. Click on the link below to have a play too …" (Teacher 4 post).

In another example, a teacher posted thoughts about collaborations with other teachers and the potential opportunities for the local community:

> "… working together to learn about and share scientific and Indigenous Sky Stories. What a great opportunity to bring together our schools and communities to explore science, technology and Aboriginal culture" (Teacher 6 post).

Figure 2 provides an example of the type of inter-school teacher collaboration and knowledge sharing. The bottom right image shows a three-school partnership. In this case they formed a teaching team to share resources and host one joint community night observation event. One advantage was that the schools could share their three telescopes to cope with the anticipated high turnout. This particular event was later attended by over 250 people and remained a fixture in the community calendar for the duration of the program. Some teachers found the construction of the telescope challenging in terms of method and organisation. Figure 2 also shows a posting depicting one student group constructing their new telescope. The image at the top shows students putting the flat pack swivel base together. Below, a student is affixing the adjustable mounts to the telescope body. Each of these tasks required the group to follow directions and work cooperatively to correctly construct their telescope.

Figure 2: A tri-school community night sky event poster and sharing how to construct a telescope

Aboriginal Education Officers (AEOs) and Community involvement

The engagement of AEOs was a key aspect of the Sky Stories program. Their abilities to offer cultural knowledge and practices, access to their local community and ability to work with students in ways different to their classroom teachers is of great value to schools, local communities and the research discussed here. During the three-year period of this study there was evidence of AEOs engaging with Facebook to deliver Australian cultural knowledge and sky stories**.** For example, one AEO was motivated to post:

> "Wander outside and by 8pm now looking east, you'll see the star Altair in the constellation of Aquila rising. For many Australian Aboriginal groups throughout the state of Victoria; and for some southern New South Wales; and for a few lower south-eastern South Australian groups, the star Altair represents the creator ancestor Bunjil. For example, in the Dreaming of the Kulin Peoples from central Victoria he is considered to be one of two moiety ancestors, the other being the Crow. Even in contemporary Aboriginal culture he is considered of prime importance and the Aboriginal Cultural Centre at the Melbourne Museum is named Bunjilaka, meaning 'place', or 'land of Bunjil'. Furthermore, Bunjil has two wives in the form of black swans that sit either side of him represented by the stars Tarazed (Gamma Aquilae) and Alshain (Beta Aquilae). The Wardaman People of the Northern Territory also see Altair as an eagle named Bulyan. For the Wardaman People, Bulyan is the eagle who watches over ceremony and keeps those away that should not be at sacred events." (AEO 2 post)

Including Indigenous perspectives in the classroom was an important component of the Sky Stories program. Students were introduced to the alternative knowledge system of Aboriginal astronomy. Along with digital and hardcopy resources, members of the local Aboriginal community (e.g., Wiradjuri, Biripi) were invited to visit schools to provide cultural insights and stories directly related to the night sky. For example, in one high school on Biripi Country, students were introduced to Aboriginal astronomy by way of a generic food collection sky story involving Emu eggs, and the possibility of hearing stories from members of the Indigenous community:

> "… learning about the Emu in the sky today. The Sky Stories project has been very well received by our students who are enjoying learning about Indigenous knowledge and

perspective. It is also a great opportunity to invite members of the local community into the school to share about their relationship with the sky" (Teacher 19 post).

There were many examples of successful collaborations between AEOs, local Aboriginal knowledge holders, performers and participating schools. Figure 3 shows students actively engaged in the story-telling process. The left image shows an AEO telling a story about sustainable fishing using the Moon and stars while students hold artworks up as a backdrop. Students designed and constructed the background with the aid of their art teacher. The event was filmed and later, images of the performance were posted on the Facebook page as an exemplar of engagement for other participating schools. The right-hand image shows students performing an interpretive dance about the Sun woman Wuriunpranalli and how she came to traverse across the sky each day.

Figure 3: AEO-1 & student groups participating in cultural story-telling

Teachers sharing work samples

Over a three-year period, teachers posted images and comments showing student engagement with the program. Posts featured both academic and hands on activities. Drawn from the Primary Connections unit *Earth's Place in Space* (supplied to each participating school), students were organised into groups to debate ideas around what they knew about Earth's position in the Solar system. Following these sessions, they were then tasked with making models to explain their understandings. Figure 4 is an example of the type of posts offered by teachers to show primary school students engaging with the Primary Connections introductory lesson, 'debating our place'. As with most of the postings by schools, it can also be seen that 258 likes were clicked, and the post had a total reach of 107 people. The evidence suggests a substantial amount of viewers were engaged in the process of following the activities. While not included in the scope of this research, it would have been interesting to know which groups (e.g., parents, community members) were liking the posts to show the spread of audience coverage.

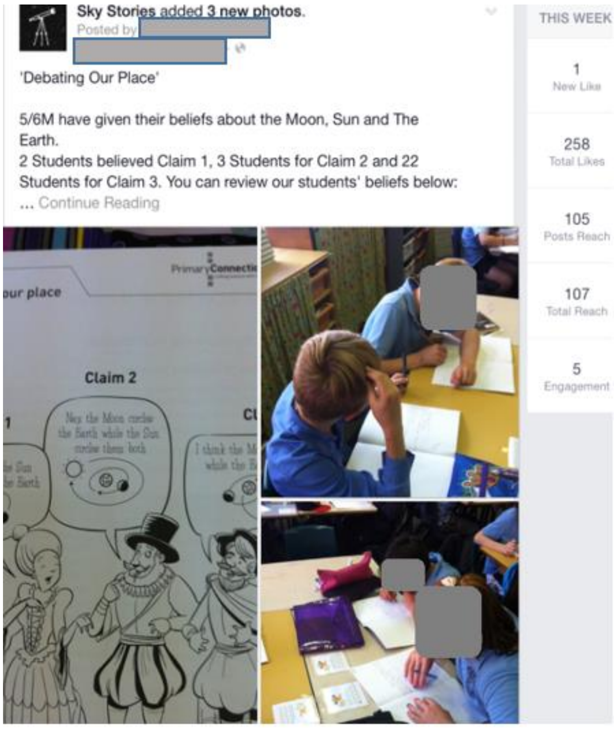

Figure 4: Teacher 2 post showing students engaging with a primary connection lesson

Figure 5 provides a snapshot from the many posts showing students engaging with model making design and construction. Teaching strategies such as whole class discussions and cooperative learning groups are noted in the commentary. Further examples of teaching approaches are shown in the following section.

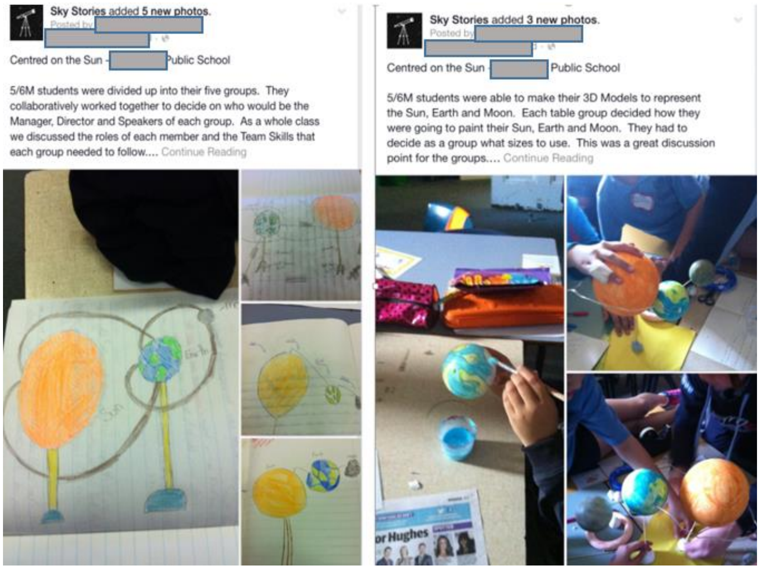

Figure 5: Teacher 3 post showing students engaging with model design and making

Student-centred teaching strategies

The previous section discussed Facebook activity related to teachers sharing examples of student learning. A closer exploration of the posts reveals evidence of student-centred teaching strategies used in the science classroom. The Sky Stories program encourages pedagogical approaches that promote meaningful teaching and learning outcomes that place the student at the forefront. A key feature of contemporary science teaching is the organisation of students into cooperative learning groups and the use of modelling and technology to develop and show understandings. Teacher experience, coupled with additional professional development and a variety of SSP resources, enabled effective classroom practices to take place. This was evidenced through teachers posting a variety of student-centred strategies. For example, students used storyboards and Power Point software to present their theories. Using video as a presentation tool was also a popular method to show their understanding of the Sun's position, in relation to the Earth and Moon. Figure 6 provides examples of posts that showed commentary, fixed images and videos of students presenting their findings and models to support their understandings.

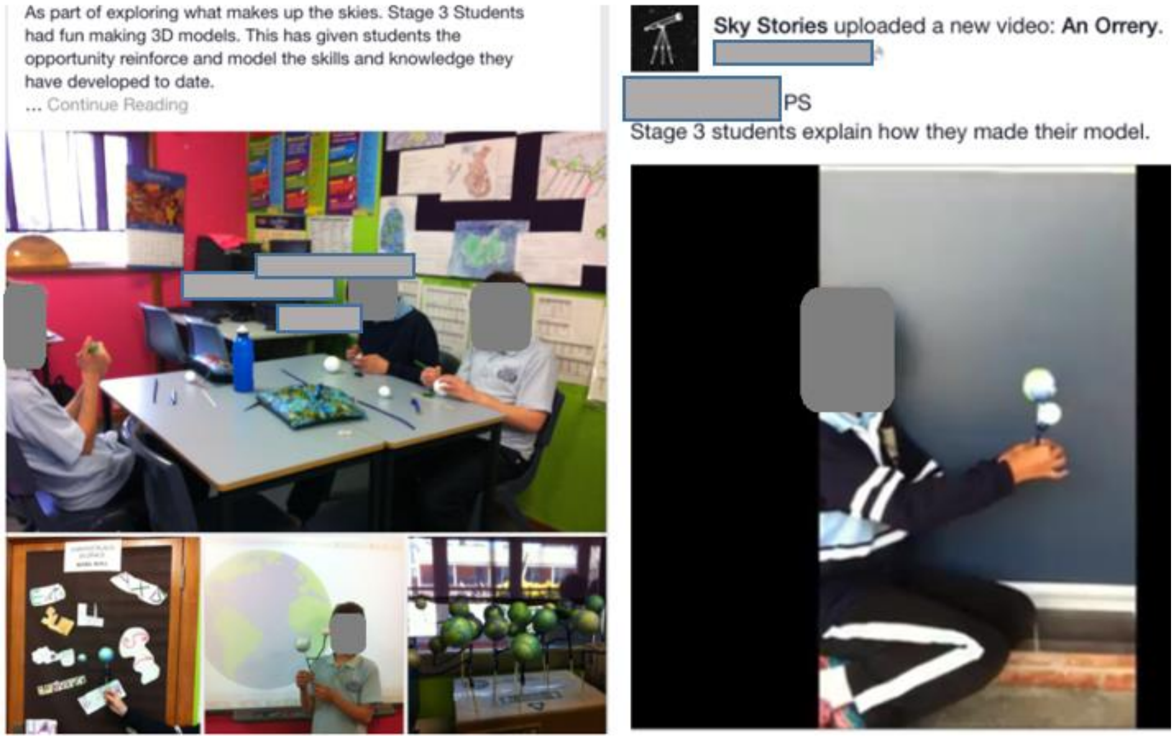

Figure 6: Teacher 4 post – Construction and presentation of models

Typical of the posts around student products were noticeboard type explanations from teachers to the Sky Stories audience. For example:

> "Today 5/6T physically modelled the movement of the Sun, Earth and Moon. The students also tested various past theories of how the Earth, Sun and Moon orbit. Students made observations, discussed theories and justified their answers with evidence (Teacher 8 post)".

Comments generated from this type of post included multiple likes and supportive responses from across the Sky Stories community. For example:

> "What a brilliant share from the students. The video has given a perfect insight into the skills and knowledge developed by the students and the act of model making has highlighted the application of their learning. Outstanding!" (Social media trainer post)

To encourage student group work activity, the SSP researcher asked teachers to let students construct their donated telescope and swivel base. At the beginning of each school term Sky Stories coordinators posted *how to build and set up your telescope* videos into the Facebook page. Student groups were formed to construct the swivel base, and set the sighting scope with the main telescope so it aligned correctly. There were many posts of students actively engaged with the construction of their telescope.

The telescope also appeared to inspire participants to investigate blended knowledge systems in astronomy. For example, one teacher posted:

> "Students at [name withheld] High School spent the afternoon preparing their telescope for a planned night of observations next week. The students have been spending their class time brushing up on their astronomy and sharing in traditional Aboriginal stories relating to the stars. Fingers crossed for a clear night!" (Teacher 5 posting).

Responding to a posted comment from the research team, the class teacher posted soon after:

> "The students loved the experience and are still buzzing. It was a great way to kick off our unit of work" (Teacher 5 Facebook - comments)

Once constructed, students and teachers were very keen to use their telescope. In a scene often repeated during the Sky Stories program, as soon as the telescope appeared, students and teachers quickly assembled to engage with it. Figure 7 shows a mobbed member of the research team who had been trying to quietly check the telescope was focussing correctly while students were in their classrooms. The students and teachers shown here were in transit to their next class.

Figure 7: Interest in a newly constructed telescope

Students were offered learning opportunities beyond the Sky Stories Unit of Work including online link ups to NASA and school visits from Astronomers. Figure 8 shows an example of students engaging with a NASA educator during a live online session.

Figure 8: Teacher 14 post - Students engaging with an interactive, online lesson

In another example of students engaging with external resources, an assistant principal posted comments about a visit by a CSIRO scientist. In this case a classroom teacher had organised the visit for the entire Stage 2 and 3 cohorts. In the post, the executive staff member names and acknowledges the classroom teacher's efforts. Along with providing evidence of student and teacher engagement with astronomy, this post is offered to show evidence of social media being used by senior staff to recognise teacher contributions and achievements:

> "An operations scientist from the CSIRO Parkes Observatory visit[s] us today. Classroom teacher [name withheld] organised for [name withheld] to speak to our Stage 2 and 3 students. He facilitated a powerful and thought provoking presentation on the Solar System, which related directly to Stage 2 and Stage 3 units of study in the Science Curriculum"
> (Assistant principal 1 post)

Community engagement

As part of the Sky Stories program, schools were encouraged to organise a school community night observation event. The events brought the community together to eat, listen to cultural stories and, in some cases, watch interpretive performances about the night sky. Viewing nights were timed to ensure various celestial objects were in view such as Venus, Jupiter and various phases of the Moon. A highlight for many families, often using a telescope for the first time, was the observation of Saturn and its rings. In an example of attendance by families, Figure 9 shows a collage of photos from three school community night observation events. The image on the top left shows a campfire scene in which a local Wiradjuri Elder told of her connection to the star cluster Pleiades. The top right-hand image shows three generations from one family sharing the use of their school telescope. As mentioned earlier, there were many instances of teachers sharing resources to cope with the wide interest in the Sky Stories night events. The bottom left image in Figure 9 shows family groups using four telescopes, two of which were on loan from nearby Sky Stories schools while the fourth one was loaned by the university research team.

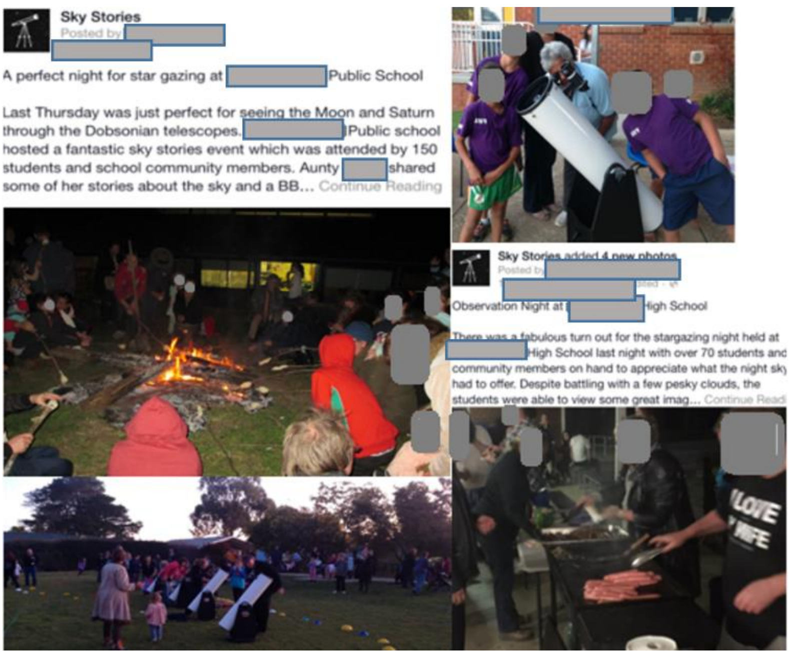

Figure 9: Community night observation event collage

Posts appeared soon after each of the community events featured multiple images and outlines of what had occurred during the night. For example:

> "More than 100 people turned out to look at the skies and some wonderful entertainment ... Students performed in dance, story retelling and listened to a didgeridoo. A sausage sizzle was enjoyed by everyone and the skies were watched. Thank you to everyone who attended and all the students and staff involved …" (Teacher 2 post).

Comments generated from this type of post included congratulatory comments from other schools, parents and the Sky Stories team. For example, following a post about a successful community night observation event, a parent was motivated to comment:

> "It was a really fun night. Important stories and info for our kiddies to be learning. Well done ☺ (Parent response comment)

Discussion

This paper has investigated the use of social media to demonstrate how schools and the communities of people can collaborate, engage and participate inclusively. The results appear to show that digital platforms such as Facebook can provide authentic evidence of involvement with school science initiatives such as the Sky Stories program. Indeed, over a three-year period the dedicated Facebook site, discussed in this paper, built a strong community of digital practices that could provide an exemplar for future research projects.

Key to getting buy-in from school executives, teachers and AEOs was the need to address online security. There is no doubt the rapid expansion of social media into schools has included elements of risks such the introduction of malware, inappropriate posts, trolling, racism and bullying. Research has shown that the human factor is the main reason problems occur and not the technology itself (e.g., Curry, 2011). Despite the mounting evidence of inappropriate activity (e.g., Carlson & Fraser, 2018), complacency forms the major impediment to ensuring all online platforms are safe to use (Davinson & Sillence, 2010). At issue here is the need to mitigate the risks by ensuring access and protocols are set up and maintained consistently and accurately. He (2012) offers five guidelines designed to ensure an organisation can operate in the digital domain with relative safety:

- Involve all relevant stakeholders;
- Enforce social media security policy;
- Update and communicate your social media policy regularly;
- Make security policies understandable for employees; and
- Protect multiple endpoints (He, 2012).

With the literature on social media security in mind, coupled with the initial surveying of potential participants, the Sky Stories team allocated funding to engage an expert in social media management for the duration of the three-year program. Once executive staff were comfortable with the platform set up, how to use it, and were aware of the support framework in place, permission to post content was granted to teaching staff. From this point on, a high level of interest in using the Facebook platform was clear.

Initially, Facebook posts were restricted to noticeboard type content. As confidence grew, the level and sophistication of content increased. Images, commentary and videos were posted showing a variety of program related activities. The expectations of audience-reach also grew from generating posts for their local school community to a broader, multi-school audience. This was evident in the posting of between-school resources and event collaborations by both executive and teaching staff. The activity appears to be consistent with the findings of Hung, & Yuen (2009) who argued that social media can serve as a valuable tool to encourage learning and generate networks that share resources.

While no students had permission to post content themselves, the Sky Stories Facebook page clearly showed student engagement and participation in both Western and

Indigenous constructs of science learning. The study showed that student enthusiasm for both knowledge systems generated authentic products such as drawings, models, hypothesis, and mixed curriculum presentations (e.g., creative arts, English, mathematics and science). Student interactions with their school telescope exceeded expectations. This engagement and participation was evident in the multiple posts showing students constructing their 'own' telescope or lining up (or crowding around it) during unplanned and formal observation events.

Student interest in telescopes and astronomy in general has typically been reported as high (Danaia, Fitzgerald & McKinnon, 2013). It followed that the aims and objectives of the Sky Stories program would not be difficult to reach. However, engaging students in Indigenous Australian astronomy was potentially problematic. Involving Indigenous knowledge holders required adept and respectful negotiations on behalf of school staff and when handled competently, often resulted in positive, meaningful interactions and knowledge sharing (e.g., story-telling and interpretive dance events). Crucial to the overall social and academic cohesion between Indigenous and non-Indigenous participants, a Wiradjuri Elder, in his capacity as an SSP team member, posted a large proportion of the Facebook content. By modelling what and how to post, and providing consistent, culturally appropriate material, Indigenous and non-Indigenous participants were kept informed and interested in events, stories and activities related to both Indigenous and Western concepts of astronomy.

The engagement of Indigenous and non-Indigenous Australian parents was of key interest to the researcher and was keenly tracked during the study. In early conversations prior to the rollout of the program, teachers raised the concern that involving the parents of Indigenous Australian students might be a challenge. The issue of non-engagement of Indigenous Australian parents in educational settings is well represented in the literature (Emerson, Fear, Fox & Sanders, 2012; Gray & Beresford, 2008). Barriers include racial prejudice, socio-economic pressures, historical trauma and cultural incompetence shown by school professionals. Intentional or not, cultural missteps have contributed to a cycle of mutual distrust at best.

Confronting this despondency and offering an inclusive and positive approach to cross-cultural teaching and learning was a key objective of the Sky Stories program. By providing both Indigenous and Western knowledge in astronomy, all parties appeared to find relevance in the program. As evident in the study, Facebook posts show images of parents engaging in activities such as cooking, watching performances, observing the night sky and generally interacting with their children during events. In terms of online activity, written responses to Sky Stories Facebook page posts by parents, appeared to be low. While it may have been technically possible to look through individual participant school Facebook sites to compare the activity of parents, it was deemed beyond the scope of the research. One possible explanation may be that parents were not comfortable commenting on the Sky Stories page and preferred to use their own, or their child's school social media as a platform for communication. Another possible explanation was that parents were only able to respond to posts and/or 'like' them. Not having authorised access may have re-directed them to alternate but related sites such as those described above. Regardless, the low activity, in terms of written responses, was intriguing and worthy of investigation in future studies.

Indigenous and non-Indigenous parents did, however, respond to calls to attend community events organised by their local schools. In almost all cases, attendance numbers exceeded expectations. The study showed that parents were excited to use the telescope and joined often very long lines for the opportunity to view various celestial objects. In scenes repeated across the Sky Stories cohort, many of the parents were reminded of their own family sky stories and were surprised to find they were of great interest to anyone listening.

Conclusion

This article has shown how social media was used show the engagement of school executives, teachers, Indigenous and non-Indigenous students, their parents and the community of which they are a part. The use of a specific Facebook page to show engagement and participation by these groups appeared to highlight the depth of interest shown in cross-cultural activities organised by schools participating in a middle-school science initiative. The study described here suggests that once security concerns are addressed, adequate training and support is provided, and executive staff buy-in is assured, digital platforms can be an important instrument for communicating contemporary teaching and learning practices both within and between local school communities. Social media can also provide opportunities to showcase ways in which Indigenous and non-Indigenous parents and community members can contribute and/or involve themselves in school activities. Having a consistent source of regular postings that models best practice in terms of tone and content is key to providing, and retaining, social cohesion and sustained interest between a wide range of participants. An opportunity exists for future cross-cultural education research to investigate other emerging social media platforms.

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Connective statement

The final paper in the series provided research on how social media was used to connect school executives, teachers, Indigenous and non-Indigenous students, their parents and their community in school science. The engagement and participation shown by the Sky Stories community demonstrates that perceived barriers can be overcome and positive, collaborative relationships can be formed or be renewed.

Educators used a dedicated Facebook page to share ideas, resources and professional achievements to a wider, digital audience. The regular contributions and interactions by Sky Stories participants led a professional community of practice (Wenger, 1998) that can potentially inform future research programs.

Implications from the research are that training, effective security protocols and a support framework must be in place prior to usage. The research showed that once school executives were satisfied that appropriate training, policies and support were in place, teachers were able to take advantage of the platform to showcase a variety of pedagogies, collaborations, student products and community involvement.

Data collected from social media shows that Indigenous and non-Indigenous students, their parents and extended families appeared to embrace the activities and events organised by their schools. Implications from the research suggests that by offering inclusive, cross-cultural, hands-on activities that are of interest to participants, new and positive science learning outcomes will follow. The next and final chapter presents the conclusion for the overall dissertation. Organised into three parts, Chapter 8 will link and summarise the overall findings of the doctoral research. Appendices that support the research are placed directly after.

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Chapter 8: Conclusion

Introduction

The purpose of this chapter is to highlight and discuss the promising frameworks, themes, limitations and implications that have been uncovered during my doctoral research. This chapter is organised into three parts. The first part re-states the overarching research question and briefly summarises the key literature which influenced and underpinned my thesis. The aims and objectives of the research are also re-stated. One very strong theme that became apparent throughout the study was the need for university researchers to engage communities in respectful, culturally appropriate ways. The practice of reciprocity emerged as a major component to building and maintaining authentic and meaningful relationships. Consistent with these findings, the second part of this chapter takes the form of a letter to the key stakeholders of the Sky Stories program. The emergent theory and findings are unpacked and discussed to acknowledge and thank those who have made countless contributions to the Sky Stories program and associated doctoral research. The final part discusses the limitations of the research and implications for future research practice.

Part 1 – Overview

Informed by the mandatory inclusion of Indigenous perspectives in the Australian Science Curriculum, this doctoral research has sought to understand how two opposing knowledge systems can be brought together to form a contemporary school science framework. Presented as a PhD with publications, five papers and one specific chapter, employed mix-method data collected over a three-year period to investigate how this might be achieved. The overarching research question stated at the beginning of my thesis is:

> How can we align conventional scientific and Indigenous knowledge systems into a contemporary school science framework?

The literature concerned with indigenous and conventional knowledge in science education research, particularly field studies, is a small but significant area of study. The review presented in Paper 1 (Chapter 2), along with smaller, more tightly focussed reviews in the remaining four papers (Chapters 3, 4, 5, and 7) showed that resolving epistemological tensions between the two knowledge systems has been, and remains, highly contentious (Aikenhead & Elliott, 2010). The literature base uses this tension to theorise how much or how little indigenous knowledge should be included in school science curricula and teaching practices (McKinley & Stewart, 2012). Early research discusses the possibilities of including indigenous knowledge in science education while ensuring the Western construct of science remains firmly in place (Aikenhead, 1996). In reaction to the current hegemony, decolonised methodologies (Martin & Mirraboopa, 2001; Smith, 1999) began to emerge in ways that either work to inform or bypass Western hegemonic research practices (Yunkaporta & McGinty, 2009).

Seeking to provide a workable solution to the dichotomy, the seminal Cultural Interface Theory was theorised by Nakata (2007). The theory places Indigenous and Western knowledge systems side by side to enable new knowledge and new realities to be realised. Cultural Interface theory is a major influence in this thesis and formed the basis and theoretical location for the doctoral research. Conducting research in this specialist area of education provided an opportunity to add new information to the corpus of literature.

The doctoral research aims and objectives re-stated here, were addressed in five papers submitted to national or international peer reviewed journals.

- Conduct a literature review targeting cross-cultural science education research over a 10-year period (2006–2016)
- Investigate whether a fully supported teaching program, that includes locally sourced Indigenous knowledge and community, can inspire students to engage with the Australian Science Curriculum
- Examine and advance theory that supports the maintenance and/or development of inclusive school communities that engage with, and share ideas about, teaching science and cultural perspectives to middle-school students
- Theorise an approach where cross-cultural school science education research can occur in authentic and ethical ways
- Explore how social media can engage school professionals, Indigenous and non-Indigenous students and their parents in school science

The next section, presented in the form of a letter, summarises the findings associated with the research aims and objectives, emergent theory, themes, and implications that have arisen from my doctoral research. As someone who grew up in New Zealand, the Maori word 'Utu' which means reciprocity and balance, was known to me. 'Utu' was a reoccurring theme that presented itself many times during my research journey and I have attempted to discuss it in several sections of my thesis. In the spirit of reciprocity and balance, I offer this letter to the stakeholders of the Sky Stories program.

Part 2 – An open letter to the Sky Stories research program stakeholders

Mutual Cultural Responsivity: Towards a Framework for Contemporary Science, my doctoral research associated with the Sky Stories program is now complete. Included in the final thesis is this letter which seeks to report on the initiative that your organisation was involved in. Equally, this letter is offered to acknowledge the invaluable support, contributions, engagement and participation you and your organisation made to the program.

The primary objective of my research associated with the Sky Stories program was to investigate a program that supported the reclamation of Indigenous Australian knowledge while deepening the value and relevance of science for teachers and students in the classroom. Discussing the impacts the program had on Indigenous and non-Indigenous students, teachers, parents, local communities and support networks, of which their participant schools are a part, was also a major part of research.

During the course of my doctoral research, I conducted a major review of cross-cultural science education research (Chapter 2). Focussing on targeted studies published between 2006 and 2016, I found that Western theoretical and methodological constructs dominated the literature base (Chapter 2). While the data showed a paucity of research programs that consider indigenous perspectives, frameworks or methodologies, there are examples of decolonised approaches that challenge the status quo (e.g., Yunkaporta & McGinty, 2009). One such framework is Cultural Interface Theory which identifies a legitimate third space between Western and Indigenous epistemologies and ontologies (Nakata, 2007). The seminal theory provided the basis for a new theoretical domain that specifically houses cross-cultural science education research (Chapters 3, 4, 5 & 7). Coined the middle-ground, the concept draws on critical research (e.g., McKinley, Brayboy & Castagno, 2008) that posits the need for a contemporary science education framework that can exist simultaneously with, and between, indigenous and Western knowledge systems in science.

As my doctoral research progressed, I identified a gap in the cultural competency guidelines currently being used by Australian institutions. The Cultural Competency Matrix, in its current form, offers a continuum pathway for practitioners, organisations and systems to develop and accumulate levels of knowledge, skills and values (Ranzijn, McConnochie, Day & Nolan, 2006). While these guidelines assist users to build the capacity to operate within the cultural domain, no model that puts this into action, by way of a response, is offered. In reaction to this gap, I conceptualised a set of guidelines coined Mutual Cultural Responsivity (Chapter 4 & 5). Defined as “a pathway for communities of culturally competent participants to produce research and experiences that satisfy a collective goal” (Chapter 5, p. 123), the Mutual Cultural Responsivity model is based on my doctoral research that argues for the need to offer multiple entry points in cross-cultural science education. That is to say, the backgrounds and standpoints of participants are unique and there is a need to allow for that fact (Chapter 4). Organised under three hierarchical stages (Awareness, Becoming & Being), the model offers a guide for users to track their experiences and absorb both their own, and other knowledge systems and worldviews. Subsequently, each user can then learn how to engage with the knowledge overlaps in a third space that is, the Middle-ground (Chapter 4).

Data from my doctoral research (Chapter 2) also showed that implementing a meaningful middle-school science education program that included Indigenous Australian perspectives, would not be possible unless high quality professional development for teachers was provided. The research also found that teachers do not have adequate cultural competency training that enables them to effectively engage with both Indigenous perspectives in teaching, and with their local Indigenous community (Chapter 5). Results from the research also found that by providing substantial roles for Elders and more broadly the local community in school science programs, would benefit all parties in terms of engagement, authenticity of knowledge production, developing meaningful teaching and learning outcomes, and building stronger community cohesion (Chapter 2).

The deficiency in training or experience was supported by discussions and interviews I conducted with participants of the program. These showed that teachers, in particular, were anxious about engaging with their local Indigenous community, and had few resources with which to teach Indigenous perspectives in science (Chapter 4). The data also shows that teachers had concerns about using social media as a way to publicly communicate their involvement in the Sky Stories program (Chapters 4 & 7). As a result, a credible face-to-face professional development program that included guidelines for school/community relationship building, an introduction to new teaching and learning resources (Appendices R–U), and adequately supported social media training, has been delivered to school participants by myself and others. Data collected from, or related to, these sessions showed that once resources, appropriate training and a support framework is put in place, executive staff and teachers felt they could implement the Sky Stories program with a much greater degree of confidence (Chapters 4, 5 & 7).

The engagement and participation of Elders, teachers, students, parents and the local community was a key theme throughout my research. In this area, a series of threads or themes emerged from my doctoral research. Valuable lessons were articulated in relation to interactions with various Indigenous Australian groups (Chapters 3 & 5). The explicit approval and involvement of Elders and/or cultural knowledge holders was a key factor contributing to the success of the overall Sky Stories program. This was achieved by conducting research in ways that respected the wants and needs of Indigenous stakeholders and the community to which they belong (Chapter 5). Once this new paradigm was put in place, increased opportunities for conducting research emerged. These data showed that when local Elders and knowledge holders presented innovative cultural story-telling practices, strong links between students, their school and their communities were formed (Chapters 3 & 5). More broadly, data collected during the Sky Stories program showed that Year 5–8 students reacted positively when offered opportunities to engage with local place-based knowledge relating to the night sky (Chapters 3, 4, 5 & 7). The data also showed that when provided with the opportunity to contribute, Elders and cultural knowledge holders helped motivate and inspire meaningful teaching and learning in the middle-school cross-cultural science domain.

Opportunities to blend other key-learning areas such as creative arts, English and Mathematics was apparent. For example, there was evidence showing students working with their teachers to design artworks and stage backdrops, performing dance and interpretations of Sky Stories through drama (Chapters 3, 5 & 7). These data also showed students preparing and presenting their findings in various ways such as through PowerPoint and videos (Chapter 7). In another example, mathematics was employed to calculate the size of planets and how to scale them down for model making (Chapter 7).

The use of social media as a data collection and communication tool proved invaluable to my overall doctoral research. My research showed that the Sky Stories Facebook page offered multiple examples of group engagement and participation in both Indigenous and Western aspects of astronomy (Chapter 7). Images and commentary posted throughout the program showed a variety of teaching and learning practices that were able to be communicated to a wider audience. The evidence suggested social media was an ideal platform with which to communicate the depth of interest in the Sky Stories program and more broadly, astronomy (Chapter 7).

In order to gain an understanding of students' perceptions about science generally, in school and in the classroom, students' responses before and after the Sky Stories program were collected, analysed and discussed. In addition, responses related to their experiences during the Sky Stories program were also analysed and discussed. Sample data was drawn from one NSW primary school and one NSW high school.

The analyses showed that students' patterns of responses were varied in terms of general science and Sky Stories related teaching and learning. Results from the sample showed that students may have become disinterested in the activities associated with the Sky Stories program. Upon closer inspection of these data, however, it appeared this may have been because teachers, who appeared to offer new pedagogical approaches, took them out of their comfort zones. Moreover, teachers who adopted contemporary practices may themselves have been uncomfortable and as a result, reverted back to transmissive approaches that ensured some semblance of control. This alternative explanation may also have been the cause of the varying responses. The results also showed that students were certainly more active and more involved. For example, the majority of students in the sample said they had used their telescope during the program, which may indicate an interest in astronomy or at the least, a preference for hands-on activities. In another example, students' patterns of responses showed that they had more opportunities to think and ask questions in the science classroom.

Cultural sky stories were delivered in a variety of ways at the two sample schools. Most students said they had listened to cultural stories about the night sky but not necessarily from Elders or Aboriginal knowledge holders. This indicated that some teachers may have by-passed engaging with local knowledge holders in favour of online resources. A response to these and other findings is included in my implications for future research section in my thesis.

The community night sky observation events that were held for students, their families and the broader local community were, arguably, the highlight of the Sky Stories program (e.g., Chapters 3, 5 & 7). The events were organised and managed by both school and community leaders. Data collected during these community gatherings showed that both Indigenous and non-Indigenous family groups attended and participated in the activities such as a barbeque and observing the night sky with telescopes. These data also highlighted the level of community interest in the cultural performances and story-telling activities presented during the events. Accompanying the evidence showing engagement and participation, the reactions of Indigenous Australian parents was of particular interest. The data showed that this group were astonished to learn that their personal sky stories, often passed down through the generations, were of immense interest to the researcher, teachers, students and the broader community alike (Chapters 3 & 5).

There has been research that discusses the enthusiasm shown by students when telescopes are introduced into school science (e.g., Fitzgerald, Hollow, Rebull, Danaia & McKinnon, 2014). My doctoral research adds to this body of work by providing new instances of student excitement, engagement and participation. As mentioned above, the majority of students used their school telescope during the Sky Stories program (Chapter 6). One theme that emerged in relation to the telescope was the sense of ownership experienced by students who took part in the construction, set up and/or use of their telescope (Chapters 3, 5 & 7). Data showed parents and other members of the school community engaged with the telescopes and were astonished to see various celestial objects (e.g., the rings of Saturn), often for the first time (Chapters 5, 6 & 7).

The Sky Stories program appears to have provided one way of delivering interesting and culturally inclusive science. Students may not have always enjoyed the content delivery but nonetheless, they appear to have been active and involved. My doctoral research associated with the program has sought to discover ways in which both Indigenous and Western constructs of knowledge can be brought together to deliver new, contemporary ways to teach middle-school science. Inclusivity, respect and reciprocity appear to be the key factors in which Indigenous Australian peoples will engage with researchers and, the context of this research, school communities. Professional development for teachers, particularly cultural competency training, also appear to be critical factors in ensuring the successful delivery of the mandatory outcomes prescribed by the Australian Science Curriculum. Indigenous and non-Indigenous students and their parents were inspired to learn more about astronomy and their Country's cultural connection to the night sky. My doctoral research may have provided a possible pathway to the problem of knowledge system alignment in middle-school science, and created the space and momentum to build a community of practice (Wenger, 1998) for future educational initiatives.

In sum, your support of the Sky Stories program and associated doctoral research has been invaluable. Your involvement has contributed to the conceptualisation of new, contemporary ways in which cross-cultural school science education can be researched and taught in schools. For all of these, I thank you.

Kind Regards

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Part 3 – Limitations of the research

This research suffers from a number of limitations in the areas of instrumentation, procedure and data collection. Primary and high schools were each provided with a Unit of Work (Appendices R and S) designed to address Indigenous and Western constructs of astronomy as required by the Australian Science Curriculum. An array of teaching and learning resources were also made available to all participating teaching teams

(Appendices T and U). Limitations were evident as, ethically, no teacher was required to teach these in the ways suggested. Consequently, control over the implementation process was problematic given the requirements to conduct ethical research in Australian schools. Fidelity of implementation was, therefore, impossible. Rather, multiple case study design, a Type IV (Yin, 2014), with multiple sources of data at multiple sites was employed to probe the peculiarities of implementation. These data showed that generally, teachers adopted and implemented what they felt their students would understand and appreciate. This approach, while not consistent with innovation adoption and implementation research in other foreign jurisdictions (e.g., Hall and Hord, 2015), is consistent with the intent of the Australian Curriculum. Here, teachers are given the professional latitude to choose appropriate pedagogies and science content in order to meet the outcomes of the Australian Curriculum.

Limitations in the procedures for collecting survey data were also evident. The pre-and post-occasion MSSQ were administered by participant teachers. However, many said they did not have the time, or their students did not have the literacy skills to complete them. Due to fluctuating attendance, the number of students completing these instruments, either individually or as a matching pre-post occasion set, was also an issue. While there can be no control over the number of students attending class on a particular day, future administration of pre-and post-occasion instruments could be tied to a timetable for completion that included the majority of the class completing them as a pre-requisite before a program proceeds. Moreover, given the ethical requirements, teachers and students cannot be forced to do this.

Limitations in the procedures while carrying out semi-structured interviews with student groups were also apparent. The researcher conducted the interviews using a list of open, questions (Appendix L) designed to elicit participants' responses. The semi-structured interview was favoured because of its ability to prompt authentic responses. However, often the timing of the interviews did not align with some of the questions. For example, some interviews were held before community night sky observation events. In other cases, student groups said they had not interacted with their telescope as yet. In reaction, the researcher may have inadvertently asked leading questions about their potential attendance at night sky events or the future use of telescopes in order to obtain answers that suited the outcomes of the study. Future studies conducted by the researcher should include clear timetabling for conducting fixed-program related interviews.

Another limitation to the data collection process was the researcher's inability to visit each of the participating schools due to both budgetary and distance constraints. Any future iterations of the program should consider the geographical spread of participants and perhaps either limit involvement or increase funding for travel. As a consequence, the inconsistent survey completion rate, inadvertent leading of questions and limited access to potential respondents may have influenced the overall data interpretation.

Not allowing for adequate time to build relationships with Indigenous communities was also identified as a limitation to the research. Because the research was conducted during a 10-week school term, limited access, and contact with, local Indigenous communities meant that only a small proportion of the community could be represented.

Part 4 – Implications for future practice

Implications for cross-cultural science school teaching practices can be taken from the findings presented across the five publications, and one specific Chapter (6), comprising this doctoral thesis. Programs such as the Sky Stories initiative have the potential to deliver significant and long-lasting changes to the way science is taught to Year 5–8 school students. Consistent with the literature (e.g., Harrison & Greenfield, 2011; Mack, et al., 2012; Oscar & Anderson, 2009), developing collaborative relationships with the local Indigenous community that included Aboriginal Education Officers, Elders and parents, was key to the engagement of students and the broader school community. Furthermore, allowing time for responses and time to build meaningful relationships is crucial when working with Indigenous Australian Elders, knowledge holders and groups. While gaining the attention of students through new teaching practices appeared to be a challenge, the research suggests that once engaged, students can be motivated to investigate astronomical content mapped to the Australian Science Curriculum. It was evident that a number of the findings have implications for future practice.

Teachers embraced the cultural elements of the program and many successes were reported, particularly in terms of extending their pedagogical repertoire. Their level of cultural confidence and competence, however, often limited their abilities to develop and/or maintain long lasting relationships with community. While this is not an isolated problem (e.g., Perso, 2012), addressing the cultural competence of school teachers in the domain of cross-cultural science education is central to developing their ability to deliver the mandatory inclusion of Indigenous perspectives as prescribed in the Australian Science curriculum. It is therefore critical to provide ongoing cultural competence training for teachers that extends past the basic capacity model. More specifically, regular training that includes opportunities for teachers to reflect and record their practice will promote opportunities to make the transition to a model that allows for more sustainable, culturally responsive collaborations.

Cross-cultural science education research has been dominated by Western research practices. The hegemony of Western approaches is maintained using a top-down method that favours academic and institutional obligations over the needs and wants of communities. Offering a more holistic approach that places the community first is critical to gaining access to authentic and meaningful Indigenous knowledge and experiences. It is, therefore, crucial that researchers consider decolonised methodologies and frameworks that respect and reciprocity in their research design. Furthermore, researchers themselves must engage with advanced models of cultural competency training to ensure cultural missteps are avoided and genuine relationships can be developed and maintained.

Conclusion

The doctoral research undertaken and described in this thesis has offered emergent theory and practical field research that has the potential to shape the way cross-cultural science education research is conducted in the future. Moreover, the overall findings shown in the five submitted papers and one specific Chapter, can inform school science teaching and learning in contemporary ways that are both practical and professionally instructive. The research provides one way for the inclusion of local Indigenous knowledge into upper primary and lower secondary school science, and provides a guide for teachers to emulate. The Sky Stories program can act as a model that demonstrates how Indigenous perspectives can be included and aligned in ways that satisfy the requirements of the Australian Science Curriculum. By operating in the middle-ground between two equally valid knowledge systems, and by employing Mutual Cultural Responsivity as a guide, new, contemporary methods of science teaching and learning can emerge.

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Appendices

Appendix A: Higher Research Ethics Committee (HREC) Approval Letter

Charles Sturt University

OFFICE OF
ACADEMIC GOVERNANCE

Private Mail Bag 29
Panorama Avenue
Bathurst NSW 2795
Australia
Tel: +61 2 6338 4185
Fax: +61 2 6338 4194

12 December 2014

Mr Nicholas Ruddell
Charles Sturt University
PO Box 8001
BATHURST NSW 2795

Dear Mr Ruddell,

Thank you for the additional information forwarded in response to a request from the Human Research Ethics Committee (HREC).

The CSU HREC reviews projects in accordance with the National Health and Medical Research Council's *National Statement on Ethical Conduct in Research Involving Humans.*

I am pleased to advise that your project entitled **"Integrating cultural sky stories and Western astronomy in middle school settings: A longitudinal case study involving students and teachers"** meets the requirements of the *National Statement*; and ethical approval for this research is granted for a twelve-month period from 12 December 2014.

The protocol number issued with respect to this project is **2014/217**. Please be sure to quote this number when responding to any request made by the Committee.

Please note the following conditions of approval:

- all Consent Forms and Information Sheets are to be printed on Charles Sturt University letterhead. Students should liaise with their Supervisor to arrange to have these documents printed;
- you must notify the Committee immediately in writing should your research differ in any way from that proposed. Forms are available at: http://www.csu.edu.au/__data/assets/word_doc/0012/963768/Report-on-Research-Project_20130503.doc (please copy and paste the address into your browser)
- you must notify the Committee immediately if any serious and or unexpected adverse events or outcomes occur associated with your research, that might affect the participants and therefore ethical acceptability of the project. An Adverse Incident form is available from the website: as above;

Approval_after_further_information.doc

Last updated: February 2014
Next review: February 2015

www.csu.edu.au
CRICOS Provider Numbers for Charles Sturt University are 00005F (NSW), 01947G (VIC) and 02960B (ACT). ABN: 83 878 708 551

Appendix B: State Education Research Applications Process (SERAP)

Approval Letter

NSW GOVERNMENT | Education & Communities

Mr Nicholas Ruddell
Charles Sturt University
PO Box 8001
BATHURST NSW 2795

CORP14/46232
DOC14/616013
SERAP 2014278

Dear Mr Ruddell

I refer to your application to conduct a research project in NSW government schools entitled *Integrating Cultural Sky Stories and Western Astronomy Concepts in Middle School Settings: A Longitudinal Case Study Involving Students and Teachers*. I am pleased to inform you that your application has been approved. You may contact principals of the nominated schools to seek their participation. **You should include a copy of this letter with the documents you send to schools.**

This approval will remain valid until 12 December 2015.

The following researchers or research assistants have fulfilled the Working with Children screening requirements to interact with or observe children for the purposes of this research for the period indicated:

Name	**Approval expires**
Nicholas William Ruddell	15/11/2018.

I draw your attention to the following requirements for all researchers in NSW government schools:

- School principals have the right to withdraw the school from the study at any time. The approval of the principal for the specific method of gathering information must also be sought.
- The privacy of the school and the students is to be protected.
- The participation of teachers and students must be voluntary and must be at the school's convenience.
- Any proposal to publish the outcomes of the study should be discussed with the research approvals officer before publication proceeds.

When your study is completed please email your report to: serap@det.nsw.edu.au.

You may also be asked to present on the findings of your research.

I wish you every success with your research.

Yours sincerely

Dr Susan Harriman
R/Director, Policy, Planning and Reporting
12 December 2014

Policy, Planning and Reporting Directorate
NSW Department of Education and Communities
Level 1, 1 Oxford Street, Darlinghurst NSW 2010 – Locked Bag 53, Darlinghurst NSW 1300
Telephone: 02 9244 5060 – Email: serap@det.nsw.edu.au

Appendix C: Information letter – Principal

PRINCIPAL LETTER/INFORMATION SHEET

Name of Research Project: Integrating cultural sky stories and Western astronomy in middle school settings: A longitudinal case study involving students and teachers.

Mr Nick Ruddell
PhD Candidate
BEd Hons
School of Teacher Education
Charles Sturt University
Bathurst NSW 2795
Ph: 02 6338 4235
Email: nruddell@csu.edu.au

Dr Lena Danaia
BEd Hons, PhD
School of Teacher Education
Charles Sturt University
Bathurst NSW 2795
Ph: 02 6338 4372
Email: ldanaia@csu.edu.au

Prof David McKinnon
BSc, DipEd, MEd, PhD
Edith Cowan University
Perth WA
Ph: (08) 6304 2482
Email: d.mckinnon@ecu.edu.au

Dr Barbara Hill
BA, MA, PhD
Division of Student Learning
Charles Sturt University
Bathurst NSW 2795
Ph: 02 633 84873
Email: bahill@csu.edu.au

Invitation

Dear [Principal Name],

You recently agreed to participate in the 2015 **Future Moves** initiative called **The Sky Stories Project.**

We are writing to invite you to take part in an educational research project that looks at investigating aspects of the **Sky Stories Project** during 2015.

The research is being conducted by Mr Nick Ruddell, a PhD candidate within the School of Teacher Education at Charles Sturt University (CSU). Nick will be investigating the impact of the **Sky Stories Project** on Science and Technology.

Before you decide whether or not you wish to participate in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

1. What is the purpose of this study?

This project will explore how your students interact with blended Indigenous and Western learning materials about the night sky, whether this experience impacts upon their perceptions and understanding of Science and Technology and whether the project has an impact on attendance patterns. The research will also examine Science and Technology teachers' perceptions of the Science and Technology they teach both before and after the **Sky Stories Project**.

2. Why have I been invited to participate in this study?

You have agreed to participate in the Future Moves **Sky Stories Project.** CSUs **Future Moves team** have provided us with your details so that you can be invited to participate in the research associated with the project. We are seeking Year 5 to 8 students and their Science and Technology teachers to participate in this research.

3. What does this study involve?

Participation in this research project involves classes undertaking surveys. One survey before students interact with the blended Indigenous and Western learning materials about the night sky, and one survey at the conclusion of the project. Each survey will be completed in class and should take approximately 30 minutes. Additionally, the researcher would like to attend a **Sky Stories Project** lesson to observe student interactions with the material. Results will only be seen by the researcher and supervisory team listed at the beginning of this letter. Participation is completely optional. In between the questionnaires, your students and their Science and Technology teachers will learn about the solar system and cultural stories relating to the night sky. Teachers, AEOs and student groups will be invited to be interviewed about their experiences during the project. This is also optional. Interviews would take approximately 25-30 minutes and will be digitally recorded with your permission. You may also be asked to supply absence data for 2015 and, if possible 2014.

4. Are there risks and benefits to me in taking part in this study?

There are no foreseeable risks associated with you taking part in this project. We anticipate that engaging in the project will increase your teachers' and students' astronomical knowledge from the perspectives of traditional Indigenous and Western knowledge systems.

5. What if I don't want to take part in this study?

Participation in this research is entirely your choice. Whether or not you decide to participate is your decision and will not disadvantage you. If you decide to participate, you may withdraw from the project at any time without giving a reason and have the option of withdrawing any data, which identifies you.

6. What if I participate and want to withdraw later?

You are free to withdraw your school's participation at any time. Any information that has been collected will be removed from the research data.

7. How will my confidentiality be protected?

Any information collected by the researcher which might identify your school will be stored securely and only accessed by the researcher and his supervisory team unless you consent otherwise, except as required by law. No identifying information will be made public.

Names will be replaced with numerical codes. Pseudonyms will be used in interview transcripts and publications.

All data related to the sky Stories Project will be kept in the researcher's office for a period of five years under lock and key. Digital data will have all identifying information removed after the construction of the longitudinal data set and stored on a password protected computer.

8. What will happen to the information that I give you?

Data will be reported in the researcher's unpublished PhD thesis. The researcher also intends to publish the data in peer-reviewed educational journals. Please note that individual participants will not be identified. Your school will have access to these peer-reviewed articles.

9. What should I do if I want to discuss this study further before I decide?

If you would like further information please contact the chief investigator: Mr Nick Ruddell on (02) 6338 6528 or email nruddell@csu.edu.au or any of the supervisory team: Dr Lena Danaia on (02) 6338 4372 or email ldanaia@csu.edu.au; or Professor David McKinnon on (08) 6304 2482 or email d.mckinnon@ecu.edu.au or Dr Barbara Hill on (02) 6338 4873 or email: bahill@csu.edu.au.

10. Who should I contact if I have concerns about the conduct of this study?

If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer:

The Executive Officer
Human Research Ethics Committee
Tel: (02) 6338 4628
Email: ethics@csu.edu.au

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.

Thank you for considering this invitation!

This information sheet is for you to keep.

Appendix D: Information letter – Teacher

TEACHER LETTER/INFORMATION SHEET

Name of Research Project: Integrating cultural sky stories and Western astronomy in middle school settings: A longitudinal case study involving students and teachers.

Mr Nick Ruddell
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Dr Lena Danaia
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Email: d.mckinnon@ecu.edu.au

Dr Barbara Hill
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Bathurst NSW 2795
Ph: 02 6338 4873
Email: bahill@csu.edu.au

Invitation

Dear [Teacher],

We are conducting an educational research project during 2015 at your school. The purpose of this letter is to extend an invitation for you to participate with your class.

The research is being conducted by Mr Nick Ruddell, a PhD candidate within the School of Teacher Education at Charles Sturt University (CSU). Nick will be investigating the impact of the **Future Moves Sky Stories Project** on Science and Technology.

Before you decide whether or not you wish to participate in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

1. What is the purpose of this study?

This project will explore how your students interact with blended Indigenous and Western learning materials about the night sky, whether this experience impacts upon their perceptions and understanding of Science and Technology and whether the project has an impact on attendance patterns. The research will also examine Science and Technology teachers' perceptions of the Science and Technology they teach both before and after the **Sky Stories Project**.

2. Why have I been invited to participate in this study?

Your principal has agreed to participate in the **Sky Stories Project** and has allowed us to make contact with you and invite you to participate. The researcher would like to capture yours and your students' thoughts about the implementation of the project.

3. What does this study involve?

Participation in this research project involves your class undertaking surveys, one survey before they interact with blended Indigenous and Western learning materials about the night sky, and one survey at the conclusion of the project. Each survey will be completed in class and should take approximately 30 minutes. Additionally, the researcher would like to attend a **Sky Stories Project** lesson to observe student interactions with the material. Results will not be shown to anyone at your school and will only be seen by the researcher and supervisory team listed at the beginning of this letter. Participation is completely optional. In between the questionnaires your class will learn about the solar system and cultural stories relating to the night sky. You may also be invited to be interviewed about your experience in the classroom. This is also optional. Interviews would take approximately 25-30 minutes and will be digitally recorded with your permission.

4. Are there risks and benefits to me in taking part in this study?

There are no foreseeable risks associated with you taking part in this project. We anticipate that engaging in the project will increase your astronomical knowledge from the perspectives of traditional Indigenous and Western knowledge systems.

5. What if I don't want to take part in this study?

Participation in this research is entirely your choice. Whether or not you decide to participate is your decision and will not disadvantage you. If you do decide to participate, you may withdraw from the project at any time without giving a reason and have the option of withdrawing any data, which identifies you.

6. What if I participate and want to withdraw later?

You are free to withdraw your participation at any time. Any information that has been collected will be removed from the research data.

7. How will my confidentiality be protected?

Any information collected by the researcher which might identify you will be stored securely and only accessed by the researcher and his supervisory team unless you consent otherwise, except as required by law. No identifying information will be made public.

Names will be replaced with numerical codes. Pseudonyms will be used in interview transcripts and publications.

All data related to the sky Stories Project will be kept in the researcher's office for a period of five years under lock and key. Digital data will have all identifying information removed after the construction of the longitudinal data set and stored on a password protected computer.

8. What will happen to the information that I give you?

Data will be reported in the researcher's unpublished PhD thesis. The researcher also intends to publish the data in peer-reviewed educational journals. Please note that individual participants will not be identified. Your school will have access to these peer-reviewed articles.

9. What should I do if I want to discuss this study further before I decide?

If you would like further information please contact the chief investigator: Mr Nick Ruddell on (02) 6338 6528 or email nruddell@csu.edu.au or any of the supervisory team: Dr Lena Danaia on (02) 6338 4372 or email ldanaia@csu.edu.au; or Professor David McKinnon on (08) 6304 2482 or email d.mckinnon@ecu.edu.au or Dr Barbara Hill on (02) 6338 4873 or email: bahill@csu.edu.au.

10. 'Who should I contact if I have concerns about the conduct of this study?'

If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer:

The Executive Officer
Human Research Ethics Committee
Tel: (02) 6338 4628
Email: ethics@csu.edu.au

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.

Thank you for considering this invitation!

This information sheet is for you to keep.

Appendix E: Information letter – Parent/guardian

PARENT/GUARDIAN LETTER/INFORMATION SHEET

Name of Research Project: Integrating cultural sky stories and Western astronomy in middle school settings: A longitudinal case study involving students and teachers.

Mr Nick Ruddell
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Dr Barbara Hill
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Division of Student Learning
Charles Sturt University
Bathurst NSW 2795
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Email:
bahill@csu.edu.au

Invitation

Dear Parent/Guardian,

We are conducting a study during 2015 at your school. The purpose of this letter is to extend an invitation for your child(ren) to join in. The research is being conducted by Mr Nick Ruddell, a PhD candidate within the School of Teacher Education at Charles Sturt University (CSU). Nick will be investigating the impact of the **Future Moves Sky Stories Project** on Science and Technology teaching at your child(ren)'s school.

Before you decide whether or not you wish your child(ren) to participate in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

1. What is the purpose of this study?

This project will explore how students interact with blended Indigenous and Western learning materials about the night sky, whether this experience impacts upon their perceptions and understanding of Science and Technology and whether the project has an impact on attendance patterns. The research will also examine Science and Technology teachers' perceptions of the Science and Technology they teach both before and after the **Sky Stories Project**.

2. Why have I been invited to participate in this study?

We are seeking Year 5 to 8 students and their Science and Technology teachers to take part in this research.

The principal has allowed us to make contact with you to invite your child(ren) to take part in this project.

3. What does this study involve?

Taking part in this research project involves your child(ren) undertaking Question and Answer (Q&A) forms. Q&A forms before their interaction with the in-class program and Q&A forms at the conclusion of the project. Each Q&A form will be completed in class and should take approximately 30 minutes. Results will not be shown to anyone at your school and will only be seen by the researcher and his supervisors. Your child(ren)'s answers to these Q&A forms do not contribute to, or alter, their school marks and taking part is completely up to you and your child(ren). In between the questionnaires your child(ren) will learn about the solar system and cultural stories relating to the night sky.

Your child(ren) may be invited to be interviewed about their experience in the classroom. This is also up to you and your child(ren). Interviews would take approximately 25-30 minutes and will be digitally recorded.

4. Are there risks and benefits to me in taking part in this study?

To the best of our knowledge there are no risks associated with you taking part in this project. We anticipate that engaging in the project will increase your teachers' and students' astronomical knowledge from the perspectives of traditional Indigenous and Western knowledge systems.

5. What if I don't want to take part in this study?

Your child(ren)'s involvement in this research is entirely your decision. If you DO NOT AGREE to your child taking part in this study, please complete the attached OPT OUT Form (Parents/Guardians) and return to your child(ren)'s teacher. We will not seek any information from your child(ren). Your child(ren) will still be able to take part in the Sky Stories Project classes and both you and your child will be able to attend the observation sessions with the telescope. If you agree to your child taking part in this study, you need DO NOTHING MORE and We will assume that you do agree.

You or your child may withdraw from the project at any time without giving a reason and have the option of withdrawing any data, which identifies you, or your child(ren).

6. What if I participate and want to withdraw later?

You are free to withdraw your child(ren)'s involvement at any time without giving a reason and have the option of withdrawing any data, which identifies your child(ren). Any information that has been collected will be removed from the research data.

7. How will my confidentiality be protected?

Any information collected by the researcher which might identify you or your child(ren) will be stored securely and only accessed by the researcher and his supervisory team unless you consent otherwise, except as required by law. No identifying information will be made public. Names will be replaced with numbers. Different names will be used in interview transcripts and publications. Data files will be retained for at least 5 years at Charles Sturt University on a password protected computer.

8. What will happen to the information that I give you?

The researchers will de-identify the information. We will analyse this information and write articles based on our findings. Information will be published in peer-reviewed educational journals.

Please note that individual students will not be identified. Your school will have access to these peer-reviewed articles.

9. What should I do if I want to discuss this study further before I decide?

If you would like further information please contact one of the chief investigators: Mr Nick Ruddell on **(02) 6338 6528** or email nruddell@csu.edu.au or Lena Danaia on **(02) 6338 4372** or email ldanaia@csu.edu.au; or Professor David McKinnon on **(08) 6304 2482** or email d.mckinnon@ecu.edu.au or Dr Barbara Hill on **(02) 6338 4873** or email: bahill@csu.edu.au.

10. 'Who should I contact if I have concerns about the conduct of this study?'

If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer:

The Executive Officer
Human Research Ethics Committee
Tel: (02) 6338 4628
Email: ethics@csu.edu.au

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.

Thank you for considering this invitation!

This information sheet is for you to keep.

Appendix F: Information letter – Student

STUDENT LETTER/INFORMATION SHEET

Name of Research Project: Integrating cultural sky stories and Western astronomy in middle school settings: A longitudinal case study involving students and teachers.

Mr Nick Ruddell
PhD Candidate
BEd Hons
School of Teacher Education
Charles Sturt University
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Dr Lena Danaia
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Prof David McKinnon
BSc, DipEd, MEd, PhD
Edith Cowan University
Perth WA
Ph: 08 6304 2482
Email d.mckinnon@ecu.edu.au

Dr Barbara Hill
BA, MA, PhD
Division of Student Learning
Charles Sturt University
Bathurst NSW 2795
Ph: 02 633 84873
Email: bahill@csu.edu.au

Invitation

Dear Student,

We are conducting an educational research project during 2015 at your school. The purpose of this letter is to extend an invitation to you to join in. The project is called **The Sky Stories Project**. Student groups in your school will have access to telescopes and blended Indigenous and Western learning materials about the night sky.

The study is being conducted by Mr Nick Ruddell from the School of Teacher Education at Charles Sturt University (CSU). Nick is a PhD student and will be reporting on the **Sky Stories Project** as part of the CSU candidature process.

Before you decide whether or not you wish to be involved in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

1. What is the purpose of this study?

In this project, we aim to explore how students' work with telescopes and blended Indigenous and Western learning materials about the night sky, whether they find this experience beneficial to their perceptions or understanding of Science and Technology, does it improve content knowledge and does the integrated nature of the project have an impact on attendance patterns. The research will also examine your teachers' understandings of the Science and Technology they teach both before and after the **Sky Stories Project**.

2. Why have I been invited to join in this study?

We have invited your teacher to join in this research and as a consequence they have agreed to include your class in the project. Your principal has allowed us to make contact with you and invite you to take part.

3. What does this study involve?

Being involved in this research project means undertaking Question and Answer surveys, one before your interaction with the telescopes and the in-class program and the second at the conclusion of the project. Each Question and Answer survey will be completed in class and should take approximately 30 minutes. **Results will not be shown to anyone at your school and will only be seen by the researcher team listed at the beginning of this letter**. Your answers to these surveys do not contribute to, or alter, your school marks and participation is completely optional. In between the Question and Answer surveys you will learn about telescopes, the solar system and cultural stories relating to the night sky. You may be invited to be interviewed about your experience in the classroom. This is also optional. Interviews would take approximately 25-30 minutes and will be digitally recorded with your permission.

4. Are there risks and benefits to me in taking part in this study?

There are no likely risks associated with you taking part in this project. We expect that engaging in the project will increase your astronomical knowledge. You will also get to access telescopes and have the opportunity to acquire your own astronomical images.

5. What if I don't want to take part in this study?

Being involved in this research is entirely your choice. Whether or not you decide to join in **is your decision** and will not disadvantage you. If you do decide to take part, **you may withdraw from the project at any time without giving a reason and have the option of withdrawing any data, which identifies you**.

6. What if I take part and want to withdraw later?

You are free to withdraw your involvement at any time. Any information that has been collected will be removed from the research data.

7. How will my confidentiality be protected?

Any information collected by the researcher which might identify you will be stored securely and only accessed by the researchers unless you consent otherwise, except as required by law. No identifying information will be made public. Names will be replaced with numbers and/or a random name called a pseudonym.

Data files will be retained for at least 5 years at Charles Sturt University on a password protected computer. All data related to the sky Stories Project will be kept in the researcher's office for a period of five years under lock and key. Digital data will have all identifying information removed after the construction of the longitudinal data set and stored on a password protected computer.

8. What will happen to the information that I give you?

The researchers will de-identify the information. We will analyse this information and write articles based on our findings. Information will be published in peer-reviewed educational journals. Please note that individual students will not be identified. Your school will have access to these peer-reviewed articles.

9. What should I do if I want to discuss this study further before I decide?

If you would like further information please contact the chief investigator: Mr Nick Ruddell on **(02) 6338 6528** or email nruddell@csu.edu.au or any of the supervisorial team: Lena Danaia on **(02) 6338 4372** or email ldanaia@csu.edu.au; or Professor David McKinnon on (08) 6304 2482 or email d.mckinnon@ecu.edu.au or Dr Barbara Hill on **(02) 633 84873** or email: bahill@csu.edu.au.

10. 'Who should I contact if I have concerns about the conduct of this study?'

If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer:

The Executive Officer
Human Research Ethics Committee
Tel: (02) 6338 4628
Email: ethics@csu.edu.au

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.

Thank you for considering this invitation!

This information sheet is for you to keep.

Appendix G: Consent form – Principal

CONSENT FORM (PRINCIPAL)

This research study is being conducted through Charles Sturt University in a sample of New South Wales State schools.

Name of Research Project: Integrating cultural sky stories and Western astronomy in middle school settings: A longitudinal case study involving students and teachers.

Mr Nick Ruddell
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Prof David McKinnon
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Edith Cowan University
Perth WA
Ph: 08 6304 2482
Email: d.mckinnon@ecu.edu.au

Dr Barbara Hill
BA, MA, PhD
Division of Student Learning
Charles Sturt University
Bathurst NSW 2795
Ph: 02 633 84873
Email: bahill@csu.edu.au

CONSENT FORM

I, ____ (PLEASE PRINT) Principal of

____ (PLEASE PRINT NAME OF SCHOOL)

consent to participation by myself and the school in the research project titled: **Sky Stories Project**.

- I understand that I am free to withdraw my participation, and that of my school in the research, at any time.
- The purpose of the research has been explained to me.
- I understand that any information or personal details gathered in the course of this research about me are confidential and that neither my name nor any other identifying information will be used or published without my written permission. Additionally I understand that completed survey instruments will be held in the researcher's office for a period of five years under lock and key. Digital data will have identifying information removed after the construction of a longitudinal data set and stored on a password protected computer.
- The Charles Sturt University Ethics in Human Research Committee has approved this study.
- I understand that if I have any complaints or concerns about this research I can contact:

  Executive Officer
  Ethics in Human Research Committee
  Charles Sturt University
  Private Bag 99
  BATHURST NSW 2795

  (02) 6338 4628

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.

Signature: ______________________________________ Date:________________________

Appendix H: Consent form – Teacher

TEACHER PARTICIPANT CONSENT FORM

Name of Research Project: Integrating cultural sky stories and Western astronomy in middle school settings: A longitudinal case study involving students and teachers.

Mr Nick Ruddell
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Dr Lena Danaia
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Ph: 02 633 84873
Email: bahill@csu.edu.au

I agree to participate in the above research project and give my consent freely.

I understand that the project will be conducted as described in the Information Statement, a copy of which I have retained.

I understand I can withdraw from the project at any time and do not have to give any reason for withdrawing.

I consent to (please tick if you agree):

☐ Complete a pre- and post-occasion survey.

☐ Having a researcher come into the classroom to observe students interacting with the curriculum material.

☐ Taking part in a 25-30 minute interview.

☐ Having my photograph taken but understand the researcher will ask my permission before capturing any image(s).

- I understand that my personal information will remain confidential to the researchers.
- I understand that completed survey instruments will be held in the researcher's office for a period of five years under lock and key. Digital data will have identifying information removed after the construction of a longitudinal data set and stored on a password protected computer.
- I have had the opportunity to have questions answered to my satisfaction.

Print Name:____

Signature: _____________________________________ Date:________________________

NOTE: Charles Sturt University's Human Research Ethics Committee has approved this project. If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer:

The Executive Officer
Human Research Ethics Committee
Tel: (02) 6338 4628 /Email: ethics@csu.edu.au.

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome**.**

Appendix I: Opt-out form for parents/guardians

Name of Research Project: Integrating cultural sky stories and Western astronomy in middle school settings: A longitudinal case study involving students and teachers.

This research study is being conducted through Charles Sturt University in a sample of New South Wales State schools. You should only sign and return this form if you DO NOT wish your child to supply information. Your child will still experience the science program but will not be asked to supply any information.

Mr Nick Ruddell
PhD Candidate
BEd Hons
School of Teacher Education
Charles Sturt University
Bathurst NSW 2795
Ph: 02 6338 4235
Email: nruddell@csu.edu.au

Dr Lena Danaia
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Prof David McKinnon
BSc, DipEd, MEd, PhD
Edith Cowan University
Perth WA
Ph: 08 6304 2482
Email: d.mckinnon@ecu.edu.au

Dr Barbara Hill
BA, MA, PhD
Division of Student Learning
Charles Sturt University
Bathurst NSW 2795
Ph: 02 633 84873
Email: bahill@csu.edu.au

OPT OUT FORM

I, ____________________________ (PLEASE PRINT) the parent/guardian/caregiver of

______________________________ (PLEASE PRINT CHILD'S NAME) **DO NOT CONSENT to my child(ren):**

- ☐ Completing in-class pre- and post-occasion survey.
- ☐ Taking part in a 25-30 minute group interview.
- ☐ Having photographs taken of them interacting with the Sky Stories Project learning materials and telescope.

Signed by: ____________________________________ Date: ____________

NOTE: Charles Sturt University's Human Research Ethics Committee has approved this project. If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer:

The Executive Officer
Human Research Ethics Committee
Tel: (02) 6338 4628
Email: ethics@csu.edu.au

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.

Appendix J: Student Pre-occasion Middle School Science & Technology Questionnaire

Student PRE-occasion Middle School Science & Technology Questionnaire

We are interested in what you think about science lessons at school.

On the following pages are some questions.

There are no right or wrong answers. We are asking for your *personal* opinion.

Please answer these questions as honestly as you can.

Date completed: ____ (Please Print)

First name: ____ (Please Print)

Year: 5 6 7 8 (Please Circle)

Class Name (i.e. 5A, 8E) ________________________________

School: ____ (Please Print)

Teacher Surname: ____ (Please Print)

Please read each sentence carefully.

Answer by putting a circle around the number that is right for you.

If you make a mistake, put a cross over it, and then circle the right number.

Look carefully at the top of each page to see how to choose or write your answer.

How often do these things happen in your Science class?

In my Science & Technology class …	Never	Rarely	Occasionally	Most of the time	Nearly every lesson
1. I copy notes the teacher gives me.	1	2	3	4	5
2. I work out explanations in science on my own.	1	2	3	4	5
3. I work out explanations in science with friends.	1	2	3	4	5
4. I have opportunities to explain my ideas.	1	2	3	4	5
5. we have class discussions.	1	2	3	4	5
6. we learn about scientists and what they do.	1	2	3	4	5
7. we do our work in groups.	1	2	3	4	5
8. look for information on the Internet at school.	1	2	3	4	5
9. investigate to see if our ideas are right.	1	2	3	4	5

How often are these things true for your science class?

During Science & Technology lessons …	Almost never	Some-times	Often	Very often	Almost always
10. I get excited about what we do.	1	2	3	4	5
11. we have enough time to think about what we are doing.	1	2	3	4	5
12. I am curious about the science we do.	1	2	3	4	5
13. I am bored.	1	2	3	4	5
14. I don't understand the science we do.	1	2	3	4	5
15. I find science too easy.	1	2	3	4	5
16. I find science challenging.	1	2	3	4	5
17. I think science is too hard.	1	2	3	4	5
18. Think and ask questions					
19. Understand and explain science ideas	1	2	3	4	5

To what extent do you agree with the following three statements?

	Strongly disagree	Disagree	Some-times	Agree	Strongly agree
20. I enjoy science *in general.*	1	2	3	4	5
21. I enjoy the science we do at *this school.*	1	2	3	4	5
22. I enjoy the science we do in *this class.*	1	2	3	4	5

Thank you for filling in this questionnaire!

Appendix K: Student Post-occasion Middle School Science Questionnaire

Student <u>POST</u>-occasion Middle School Science & Technology Questionnaire

We are interested in what you think about science lessons at school.

On the following pages are some questions.

There are no right or wrong answers. We are asking for your *personal* opinion.

Please answer these questions as honestly as you can.

Date completed: ____ (Please Print)

First name: ____ (Please Print)

Year: 5 6 7 8 (Please Circle)

Class Name (i.e. 5A, 8E) ________________________________

School: ____ (Please Print)

Teacher Surname: ____ (Please Print)

Please read each sentence carefully.

Answer by putting a circle around the number that is right for you.

If you make a mistake, put a cross over it, and then circle the right number.

Look carefully at the top of each page to see how to choose or write your answer.

How often do these things happen in your Science class during the sky Stories Project?

In my Sky Stories Project science class …	Never	Rarely	Occasionally	Most of the time	Nearly every lesson
1. I copied notes the teacher gave me.	1	2	3	4	5
2. I worked out explanations in science on my own.	1	2	3	4	5
3. I worked out explanations in science with friends.	1	2	3	4	5
4. I had opportunities to explain my ideas.	1	2	3	4	5
5. we had class discussions.	1	2	3	4	5
6. we learned about scientists and what they do.	1	2	3	4	5
7. we did our work in groups.	1	2	3	4	5
8. looked for information on the Internet at school.	1	2	3	4	5
9. investigated to see if our ideas are right.	1	2	3	4	5

How often are these things true for your Sky Stories Project, science class?

During science lessons …	Almost never	Some-times	Often	Very often	Almost always
10. I got excited about what we were doing.	1	2	3	4	5
11. we had enough time to think about what we were doing.	1	2	3	4	5
12. I was curious about the science we were doing.	1	2	3	4	5
13. I was bored.	1	2	3	4	5
14. I didn't understand the science we were doing.	1	2	3	4	5
15. I found science too easy.	1	2	3	4	5
16. I found science challenging.	1	2	3	4	5
17. I thought science was too hard.	1	2	3	4	5
18. Think and ask questions	1	2	3	4	5
19. understand and explain science ideas	1	2	3	4	5

To what extent do you agree with the following three statements?

	Strongly Disagree	Disagree	Some-times	Agree	Strongly Agree
20. I enjoy science *in general.*	1	2	3	4	5
21. I enjoy the science we do at *this school.*	1	2	3	4	5
22. I enjoy the science we do in *this class.*	1	2	3	4	5

Indicate how often these things happened.

During the Sky Stories Program, we ...	Never	1 day per year	2-3 days per year	4-5 days per year	6+ days per year
23. Used or visited the Sky Stories Facebook page	☐	☐	☐	☐	☐
24. Listened to visiting speakers who talked to us about science	☐	☐	☐	☐	☐
25. Attended a night sky observation evening	☐	☐	☐	☐	☐
26. Used the telescope during a science lesson	☐	☐	☐	☐	☐
27. Listened to cultural stories about the night sky	☐	☐	☐	☐	☐
28. Engaged with the local Aboriginal community	☐	☐	☐	☐	☐

Thank you for filling in this questionnaire!

Appendix L: Student interview schedule

Interview schedule

"Sky Stories Program"

- Sky Stories Program participants in groups of 4
- Interview responses recorded on handheld audio device

1. **What have you been doing in science at school during the Sky Stories Program?**

   a. What kinds of things have you been learning? What else? For example, did you make a scale model of the Solar System? OR measure the distance to the Moon? Did you hear any cultural sky stories?

   b. If students mention that they have been sharing/listening to different sky stories ask them about the experience/how were the stories delivered/did they access any stories online?

   c. Did you access any of the SSP learning materials online? How did you find them?

   d. Did you interact with the SSP Facebook page?

   Has your class/school held an observation evening with your new telescope?

   a. What was it like? Tell me about the night. What did you observe? Did your parents/guardians attend the evening? Did you practice setting up the telescope? Did you use Stellarium to help you identify/navigate to various objects?

   b. What lead in work did you do (if any) before the observation session?

2. **What part of the Sky Stories Program interested you the most?**

   a. Give me an example of something that you enjoyed? What happened? Give me an example of a science lesson that you enjoyed. What happened?

   b. Give me an example of something that you did not enjoy/like? What happened? Why didn't you like it? Give me an example of a science lesson that you did not enjoy. What happened?

3. **What changes would you like to see made to the Sky Stories Program if it was done again?**

   a. Have you told your parents/friends about what you have been doing in class? What do they think of the project?

   b. Would you like to be taught other science subjects in this way?

4. **Would you like to comment further on your experiences/the Project?**

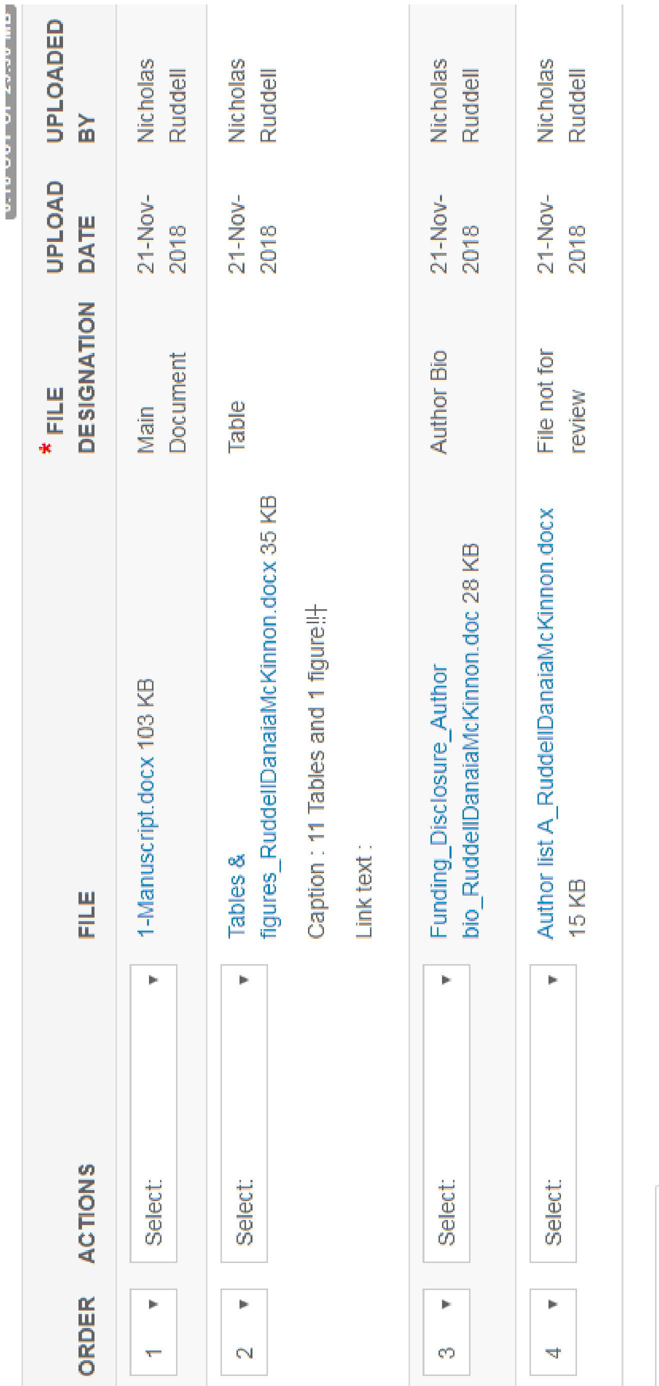
Probing questions

- Why?
- Why do you say that?
- What do you mean?
- What did it do for you?
- What gives you that impression?
- Why do you think that?
- What else?
- What other …?
- How else?
- How have you been doing that?

Congruent with Child Protection Guidelines the chief researcher, Mr Nicholas Ruddell, is a qualified primary school teacher (Bachelor Education (Prim) (Hons 1)). Mr Ruddell has a current working with children check: Number WWC0007343E. Ethical approval has been granted by the NSW Department of Education and Communities State Education Research Applications Process (SERAP 2014278), and the Human Research Ethics Committee (HREC 2014/217) at Charles Sturt University. If you have any concerns about the conduct of the study, you may contact the HREC committee through the executive officer: Tel: (02) 6338 4628 Email: ethics@csu.edu.au

Appendix M: Paper 1 – evidence of journal submission

Paper 1 entitled *A review of literature of school science programs addressing indigenous perspectives: Developing and using criteria to assess research findings over a 10 year period (2006-2016)* was submitted to the Asia Pacific Journal of Education (APJE) on 21 November 2018. Figure 1 shows submission details extracted from the journal site.



ORDER	ACTIONS	FILE	* FILE DESIGNATION	UPLOAD DATE	UPLOADED BY
1	Select:	1-Manuscript.docx 103 KB	Main Document	21-Nov-2018	Nicholas Ruddell
2	Select:	Tables & figures_RuddellDanaiaMcKinnon.docx 35 KB Caption : 11 Tables and 1 figure!!+ Link text :	Table	21-Nov-2018	Nicholas Ruddell
3	Select:	Funding_Disclosure_Author bio_RuddellDanaiaMcKinnon.doc 28 KB	Author Bio	21-Nov-2018	Nicholas Ruddell
4	Select:	Author list A_RuddellDanaiaMcKinnon.docx 15 KB	File not for review	21-Nov-2018	Nicholas Ruddell

Figure 1: Screenshot of the APJE submission dashboard.

Appendix N: Paper 2 – evidence of journal submission

Paper 2 entitled *Indigenous Sky Stories one case-study: Reframing how we introduce primary school students to astronomy* was published in the Australian Journal of indigenous Education (AJIE) on 25 November 2016. Figure 2 shows the journal search results by title.

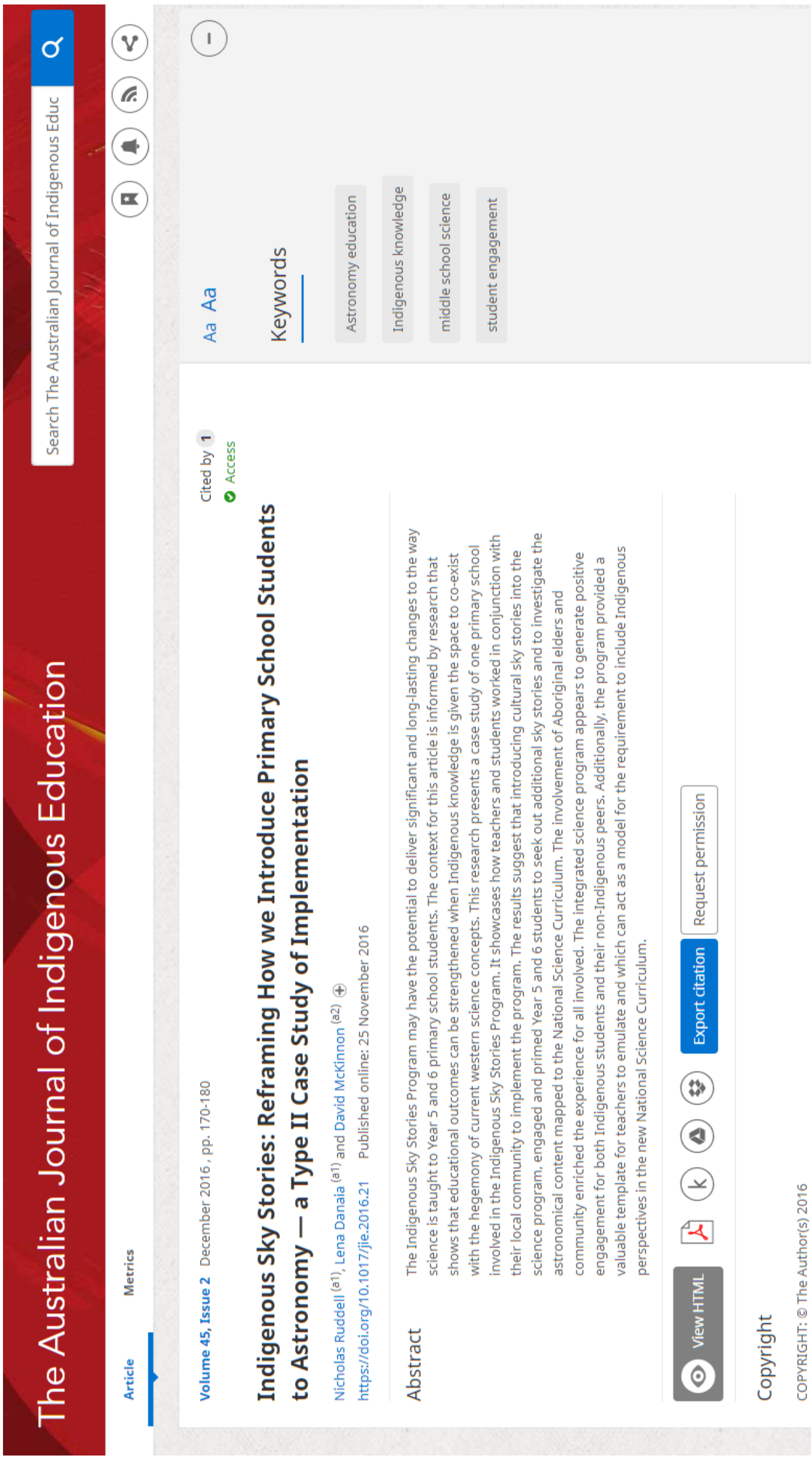


Figure 2: AJIE search results by title

Appendix O: Paper 3 – evidence of journal submission

Paper 3 was re-submitted to Cultural Studies in Science Education (CSSE) on 7 December 2018 following a request from the Editor to modify the original document. The current status as of 21 December 2018 is recorded as *Editor Assigned.* Figure 3 shows a screenshot taken from the CSSE dashboard.

Revisions Being Processed for Author Nicholas W Ruddell, Honours

Page: 1 of 1 (1 total revisions being processed) Display 10 results per page.

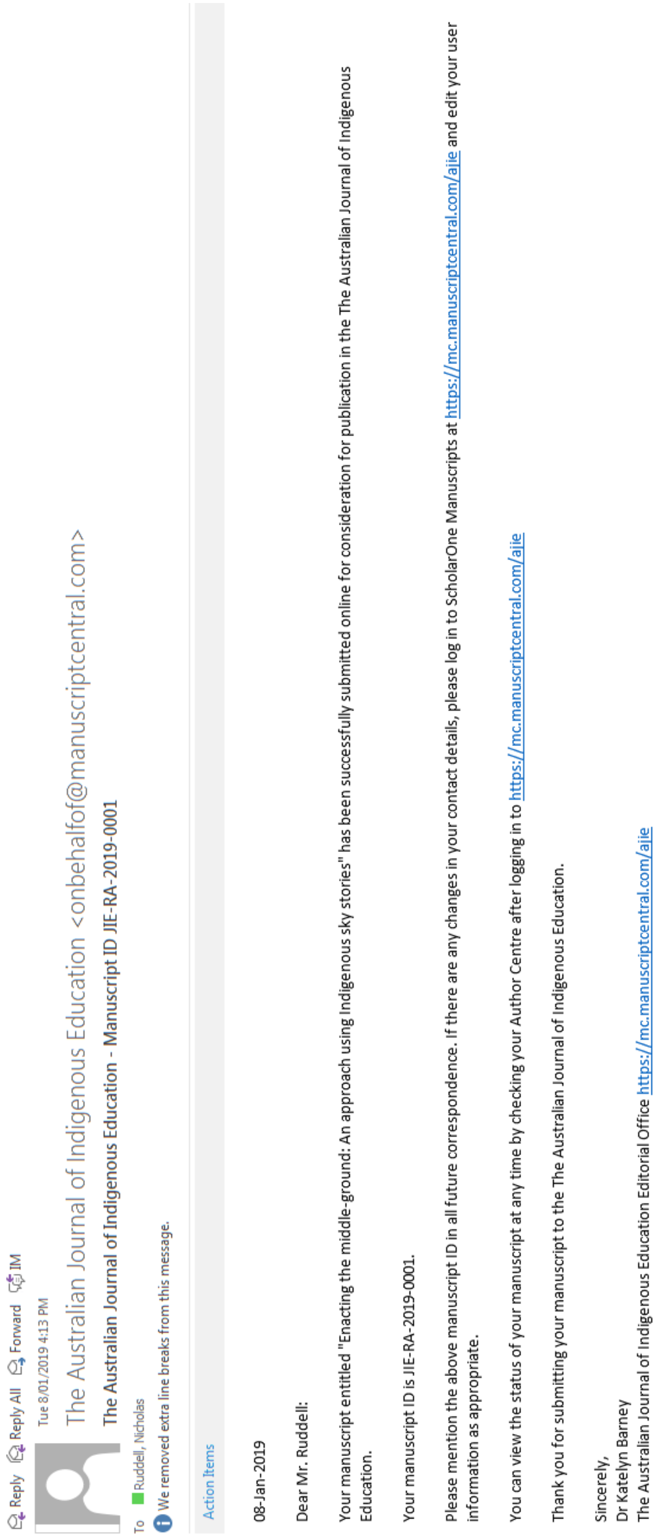
Action	Manuscript Number	Title	Date Submission Began	Status Date	Current Status
Action Links	CSSE-D-18-00051R1	Working towards a contemporary understanding of mutual cultural responsivity in school science: An Australian perspective	02 Jul 2018	05 Jul 2018	Editor Assigned

Page: 1 of 1 (1 total revisions being processed) Display 10 results per page.

Figure 3: CSSE submission status

Appendix P: Paper 4 – evidence of journal submission

Paper 4 was submitted to The Australian Journal of Indigenous Education (AJIE) on 8 January 2019. Figure 4 shows an email from the editorial office confirming the submission.



Reply Reply All Forward IM

Tue 8/01/2019 4:13 PM

The Australian Journal of Indigenous Education <onbehalfof@manuscriptcentral.com>

The Australian Journal of Indigenous Education - Manuscript ID JIE-RA-2019-0001

To Ruddell, Nicholas

We removed extra line breaks from this message.

Action Items

08-Jan-2019

Dear Mr. Ruddell:

Your manuscript entitled "Enacting the middle-ground: An approach using Indigenous sky stories" has been successfully submitted online for consideration for publication in the The Australian Journal of Indigenous Education.

Your manuscript ID is JIE-RA-2019-0001.

Please mention the above manuscript ID in all future correspondence. If there are any changes in your contact details, please log in to ScholarOne Manuscripts at https://mc.manuscriptcentral.com/ajie and edit your user information as appropriate.

You can view the status of your manuscript at any time by checking your Author Centre after logging in to https://mc.manuscriptcentral.com/ajie

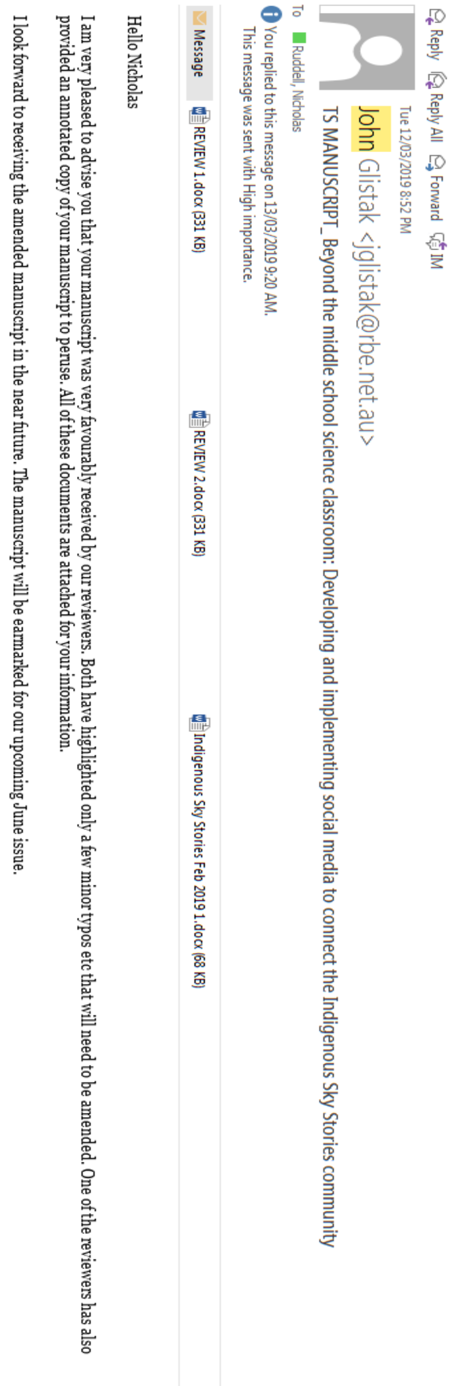
Thank you for submitting your manuscript to the The Australian Journal of Indigenous Education.

Sincerely,
Dr Katelyn Barney
The Australian Journal of Indigenous Education Editorial Office https://mc.manuscriptcentral.com/ajie

Figure 4: AJIE submission

Appendix Q: Paper 5 – evidence of journal submission

Paper 5 was submitted to The Australian Science Teachers Associations primary publication: Teaching Science. The procedure requires submission by email. An email containing the manuscript, figures and images, and the mandatory Teaching Science Manuscript Submission Form, was sent to publications@asta.edu.au on 14 February 2019. Figure 5 shows an email from the editorial office confirming the acceptance of the article subject to minor editing.


Reply Reply All Forward IM

Tue 12/03/2019 8:52 PM

John Glistak <jglistak@rbe.net.au>

TS MANUSCRIPT_Beyond the middle school science classroom: Developing and implementing social media to connect the Indigenous Sky Stories community

To Ruddell, Nicholas

You replied to this message on 13/03/2019 9:20 AM.
This message was sent with High importance.

Message REVIEW 1.docx (331 KB) REVIEW 2.docx (331 KB) Indigenous Sky Stories Feb 2019 1.docx (68 KB)

Hello Nicholas

I am very pleased to advise you that your manuscript was very favourably received by our reviewers. Both have highlighted only a few minor typos etc that will need to be amended. One of the reviewers has also provided an annotated copy of your manuscript to peruse. All of these documents are attached for your information.

I look forward to receiving the amended manuscript in the near future. The manuscript will be earmarked for our upcoming June issue.

Figure 5: ASTA-TS acceptance

Appendix R: Sky Stories Primary School Unit of Work Document

Sky Stories Primary School Unit of Work Overview

Materials: Primary Connections *Earth's place in Space* + additional Indigenous Perspectives			
Time allocation: Term 3 – Tuesday 14 July–Friday 18 September			
Week(s)	**Activity 1**		**Activity/Assessment**
1	**Before** unit commences: 1. Administer PRE-occasion Middle School Student Questionnaire **Time: 30 minutes**		A CSU representative will arrange the collection of the completed questionnaires **Time: 30 minutes**
	DONE/DATE__________	**DONE/DATE__________**	
2	Introduce class to Sky Stories concept using selected resources from CSU Future Moves website: [LINK REMOVED] Go to the Sky Stories Facebook page to view content [LINK REMOVED] **Time: 30 minutes**	Set up Telescope Watch instructional videos found on CSU Future Moves website. [LINK REMOVED] & construct (2-4 Students) **Time: 45 minutes**	Sun and/or daytime Moon observation 99.9998% of the Sun's harmful light is eliminated by your solar filter so your students can safely view the Sun. The Moon is also able to be seen. **Time: 40 minutes**
	DONE/DATE__________	**DONE/DATE__________**	
3	Go to: Australian Aboriginal astronomy Knowledge: ABC Resource: Emu in the Sky and other sky stories. [LINK REMOVED]. Interesting and informative website contains stories images and links. Headings include First Astronomers, the sky as a calendar and keeping the Aboriginal night sky alive. Or read stories from Wiradjuri/ Kamilaroi Astronomy Report (see CSU Future Moves learning resources) [LINK REMOVED] **Time: 45 minutes**	Go to: ABC: Dust Echoes – multimedia website. [LINK REMOVED] **Dreamtime animated stories, quizzes, worksheets. Includes teacher guides.** Night sky related stories are: the morning star, Namorrodor (a shooting star - visuals and music only) and the moon man. Includes study guides and worksheets. Students can also make their own videos in the *Mash it up* section. **Time: 45 minutes**	Note: Classes with no access to computers can do the series in hardcopy format (see CSU Future Moves learning resources) [LINK REMOVED]
	DONE/DATE__________	**DONE/DATE__________**	
4 Primary Connection lesson #1 (see PC handbook)	Session 1: how scientists think using Eratosthenes Earth is flat activity. –Students debate about positional relationship between Earth, Moon and Sun Populate a KTWLH chart **Time: 45 minutes**	Session 2: Centred on the Sun –CLGs develop 3D models of Earth Moon and Sun and present theories. Students work on glossary. Students tasked to observe and record movement of the Moon at home. **Time: Optional**	How the Earth is part of a system of planets orbiting a star (Sun) ACU078
	DONE/DATE__________	**DONE/DATE__________**	
5 PC lesson #2 (see PC handbook)	Session 1: CLGs develop flow charts from the collected evidence (photos, telescope observations, Stellarium) of Earth Moon and Sun movement over several hours. **Time: Optional**		How planets in the Solar System orbit the Sun, and Moons orbit the planets. ACSU078
	DONE/DATE__________	DONE/DATE__________	

6 PC lesson #3 (see PC handbook)	CLGs use and present models of Earth Moon and Sun movements that could explain the apparent movement of the sun and Moon in the sky. **Time: Optional**	Indigenous Perspectives – Invite local community members to share traditional explanations about the origins and movement of the Sun and the Moon. OR... Use resources such as the Murray Cod Story lesson plan found on CSU Future Moves learning resources. [LINK REMOVED] **Time: Optional**	How planets in the Solar System orbit the Sun, and Moons orbit the planets. ACSU078
	DONE/DATE__________	**DONE/DATE__________**	
6 20th Aug	Suggested School/ community night observation event – BBQ, telescopes, cultural performances Schools are encouraged to post digital learning outcomes, images, performances onto the Sky Stories CSU FM Facebook page. [LINK REMOVED]	The Future Moves team can help organise your event. A waxing crescent Moon will be in the night sky. Celestial objects to look out for will be posted on the Sky Stories CSU FM Facebook page [LINK REMOVED]	
	DONE/DATE__________	**DONE/DATE__________**	
7 PC lesson #6 (see PC handbook)	Session 1: Dealing with data Investigate characteristics (Size and distance) of objects in the Solar System **Time: Optional**	Session 2: Size matters Create 3D model of Solar System Visualise the Solar System's place in space. **Time: Optional**	Summative: refer to online PC rubrics Primary Connections Rubrics [LINK REMOVED]
	DONE/DATE__________	**DONE/DATE__________**	
8 PC lesson #7 (see PC handbook)	Session 1: Earth's place in space discussion using TWLH chart Encourage students to give both traditional and contemporary concepts.	Session 2: Students construct a dialogue between two people each believing a different claim about the characteristics position and movement of the Earth, Moon and Sun. Encourage students to give both traditional and contemporary concepts.	How the Earth is part of a system of planets orbiting a star (Sun) (ACU078) Summative: refer to online PC rubrics https://www.primaryconnections.org.au/ [LINK REMOVED] A log-in will need to be set up.
	DONE/DATE__________	**DONE/DATE__________**	
9 Case-Study schools	Unit completed: 1. Administer POST-occasion Middle School Student Questionnaire 2. TEACHER to fill in Unit of Work Done/Dates Time: 40 minutes	Unit completed:	A CSU representative will organise the collection of the completed questionnaires and Unit of Work documents
	DONE/DATE__________	**DONE/DATE__________**	
Additional activities			

Appendix S: Sky Stories Primary School Unit of Work Document

Sky Stories Project
High School Unit of Work Overview

<table>
<tr><td colspan="2">2015 National Curriculum – mapping School: Teacher:</td></tr>
<tr><td colspan="2">Materials: Science by Doing resources, Sky Stories Project Activity booklet + additional Indigenous Perspectives</td></tr>
<tr><td colspan="2">Time allocation: approximately 12.5 hours</td></tr>
<tr><td>Science as a human endeavour
Nature and development of science
Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world (ACSHE119)</td><td>Science Inquiry Skills
Planning and conducting
Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125)
View additional details about Literacy View additional details about Critical and creative thinking View additional details about Personal and social capability View additional details about Ethical understanding</td></tr>
<tr><td>Earth and space sciences
Predictable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the sun, Earth and the moon (ACSSU115)</td><td>http://syllabus.bos.nsw.edu.au/science/science-k10/content/983/
A student:
› describes the dynamic nature of models, theories and laws in developing scientific understanding of the Earth and solar system SC4-12ES
ES2 Scientific knowledge changes as new evidence becomes available. Some technological developments and scientific discoveries have significantly changed people's understanding of the solar system.
Students:
a. explain that predictable phenomena on the Earth, including day and night, seasons and eclipses are caused by the relative positions of the sun, the Earth and the moon (ACSSU115)
b. demonstrate, using examples, how ideas by people from different cultures have contributed to the current understanding of the solar system
c. compare historical and current models of the solar system to show how models are modified or rejected as a result of new scientific evidence</td></tr>
</table>

Before unit commences: 1. Administer the PRE-occasion Middle School STUDENT Questionnaire 30-35 minutes **A CSU representative will arrange to collect the completed questionnaires** ***Time: 30-35 minutes**	Visit an ABC Resource: Emu in the Sky and other sky stories http://www.abc.net.au/science/articles/2009/07/27/2632463.htm?site=science/indepthfeature "Astronomy didn't start with the Greeks. Thousands of years earlier Aboriginal people scanned the night sky, using its secrets to survive the Australian landscape". Interesting and informative website contains stories images and links. Headings include: First Astronomers, The sky as a calendar and Keeping the Aboriginal night sky alive.	Set up Telescope Watch instructional video found on Http://www.csu.edu.au/future-moves & construct (2-4 Students) **Time: 45 minutes**	
DONE/DATE ______/_________	DONE/DATE ______/___________	DONE/DATE ______/___________	
Sun and/or daytime Moon observation – Along with observing the night sky, the telescope can be used during class time. 99.9999% of the Sun's harmful light is eliminated by your solar filter so your students can safely view the Sun. The Moon is also able to be seen. Viewing the Moon during the day provides excellent opportunities for students to confront their conceptions about the position of the Moon in relation to night and day. Look within a week or so of the date of full Moon. Before full Moon, look for the daytime Moon in the *afternoon*.	**SBD 5.1 Digital resource – Explore** http://www.scootle.edu.au/ec/pin **Scootle student pin: MPUWUV** Night and day: Watch an animation of the Earth rotating in space showing day and night, the equinox where locations on Earth experience close to equal hours of daytime and night-time and views of the Earth from above the North and South Poles. Turn an animated model of the Earth to explore how rotation is related to night and time of day. Answer a series of questions by experimenting with the model.	Indigenous Perspectives – Invite local community members to share traditional explanations about the origins and movement of the Sun and the Moon. **OR ...** Use resources such as the Murray Cod Story lesson plan found on CSU Future Moves learning resources http://www.csu.edu.au/future-moves **Time: 40/120+ minutes**	**SBD 6.9 Digital resource** Explore and Elaborate Predictable Phenomena: Australian Indigenous calendars Students read brief introduction, listen to BBC podcast (18 minutes) Watch video: Emu in the sky (2:19 minutes) **Total time: 25 minutes**

After full Moon, look for the daytime Moon in the *morning*. **Time: 40 minutes**	*Alternatively, you can use the practical day and night activity (see PDF: Sky Stories Project Activity booklet Stage 4). **Time: 30–40 minutes**		
DONE/DATE ______/___________	DONE/DATE ______/___________	DONE/DATE ______/___________	DONE/DATE ______/___________
SBD 5.9 Digital resource http://www.scootle.edu.au/ec/pin **Scootle student pin: XHGJVY** The Seasons: Students click through to animated digital models that explain how seasons occur **Time: 15–25 minutes**	**Modelling the Seasons** The Seasons: Students use a globe and light source to model the Seasons (see Sky Stories Project Activity booklet, Stage 4). **Time: 25 minutes**	**SBD 5.11 Digital resource** http://www.scootle.edu.au/ec/pin **Scootle student pin: YKBTUN** The Seasons: Students will complete two interactive quizzes to formatively test their understanding of how the Earth's orbit and the Sun's energy affect the seasons **Time: 40 minutes**	**SBD 5.12 Digital resource** The Seasons: Student investigation: do we always observe four seasons: Students will find information and two links: A precious heritage and Indigenous Weather knowledge. **Time: 30 minutes**
DONE/DATE ______/_________	DONE/DATE ______/___________	DONE/DATE ______/___________	DONE/DATE ______/___________
SBD 6.1 Digital resource/class activities Why does the Moon change shape? Students click through to the Dust Echoes website and watch an animated Dreamtime creation story. A study guide can be downloaded for further activities. **Time: 30/60+ minutes**	Hands on inquiry Explain and Elaborate Observing the Moon: Students keep a Moon observation journal. (see Sky Stories Project Activity booklet Stage 4). Note: You could commence this activity at the start of the term to allow students to collect data over a full lunar cycle. **Time: One lunar cycle**	Explore and explain **SBD 6.3 Digital resource** Waxing and waning: students click through to digital models and an animated video that explains the Lunar cycle. Note: while good, the video is for Grade 2. http://bit.ly/MYF9en **Time: 30–40 minutes**	Evaluate **Classroom modelling activity** What do you know about the phases of the Moon? Students apply their knowledge of the Moon and its phases to the relative positions of the Earth, Moon and Sun (see PDF: Sky Stories Project Activity booklet Stage 4). **Time: 40 minutes**
DONE/DATE ______/___________	DONE/DATE ______/___________	DONE/DATE ______/___________	DONE/DATE ______/___________

SBD 4.2 Digital resource Engage Stargazing: read short text about **telescopes** and space exploration **Time: 10 minutes**	**SBD 4.3 Digital resource** Engage Constellations: read a short text about constellations, hover mouse over clusters for names. *Find out more* option offers alternative names by the Boorong people *Students explore folklore around Indigenous Australian constellations and compare to Greek constellations. **Time:10/40 minutes**	**SBD 4.8 Digital resource** Engage and Explore Our Solar System: Students write down some ideas they have on the Solar system then click through to a fun NASA website. Facts, games and good graphics. No difficult tasks here. http://spaceplace.nasa.gov/solar-system-explorer/en/# **Time: 30 minutes**	**Whole class activity** Engage and Explore Modelling the solar System can be taken outside. (see PDF: Sky Stories Project Activity booklet Stage 4). **Time: 2 x 40 minutes**
DONE/DATE ______/_________	DONE/DATE ______/___________	DONE/DATE ______/___________	DONE/DATE ______/___________
At home students observe a star and record its apparent movement **Time: optional**			
DONE/DATE ______/_________			
20th Aug - Suggested School/ community night observation event – BBQ, telescopes, cultural performances The Future Moves team can help organise your event. Schools are encouraged to post digital learning outcomes, images, performances onto the Sky Stories Facebook page. A waxing crescent Moon will be in the night sky. Celestial objects to look out for will be posted on the Sky Stories Facebook page **Time: 2–4 hours**		**At the end of the Unit (approximately week 8-9)** 1. Administer POST-occasion Middle School STUDENT Questionnaire 2. TEACHER to fill in Unit of Work Done/Dates A Future Moves representative will collect the completed questionnaires **Time: 40 minutes**	
DONE/DATE ______/___________		DONE/DATE ______/___________	
Any additional lessons/activities?			

–*All activity times are approximate.

Appendix T: Cultural studies resource pack

Sky Stories Project – Indigenous Perspectives Resource Kit

This document contains a list of resources related to Indigenous Australian astronomy and the Dreamtime. The guide is divided into six sections. Section one offers reviewed websites. Section two provides videos found on YouTube and on the CSU Sky Stories Project site. Section three provides a list of books. Section four provides a list of activities for classrooms that may not have access to multiple online computers. Section five provides an ABC audio link. Section six provides access to some teacher reading material.

Section one – Interactive websites

ABC Resource: Emu in the Sky and other sky stories

http://www.abc.net.au/science/articles/2009/07/27/2632463.htm?site=science/indepthfeature

"Astronomy didn't start with the Greeks. Thousands of years earlier Aboriginal people scanned the night sky, using its secrets to survive the Australian landscape."

- Interesting and informative website contains stories images and links. Headings include First Astronomers, the sky as a calendar and keeping the Aboriginal night sky alive.

There is also a very good **Related Stories** section on the right side of the page ...

- Click the **audio** link titled **Indigenous Astronomy** to hear a 10-minute talk with ethno-astronomer Ray Norris.
- Click **Aboriginal Astronomers** for stories, images and facts about the **Emu in the Sky**.
- Click **Beyond Galileo** for in depth text on traditional Australian astronomy. The text is a series of discussion points about, how scientists are uncovering new information about ancient traditional knowledge. The text includes traditional sky story knowledge that has been passed down through the generations.
- Click on **Tnorala – Message stick ABC TV** to read about Tnorala, a land formation in Central Australia that rises above the plains fringing the edge of Western MacDonnell Ranges. According to the stories handed down to senior storyteller, Mavis Malbunka, the distinctive crater-shaped landmark was formed during the Dreamtime, when a baby fell to earth from its resting place among the stars.

ABC: Dust Echoes – multimedia website

http://www.abc.net.au/dustechoes/

An excellent collection of dreamtime animated stories, quizzes, worksheets. Includes teacher guides.

- Night sky related stories are: **the morning star**, **Namorrodor** (a shooting star – visuals and music only) and **the moon man**. Includes study guides and worksheets. Students can also make their own videos in the **Mash it up** section.
- Classes with no access to computers can do the series in hardcopy format (see section four for details)

Australian Government website / the Dreaming

http://australia.gov.au/about-australia/australian-story/dreaming

- Short selection of easy to read sky stories. Scroll down to Stories of the stars and sky to read about traditional knowledge from the Torres Strait islands, Northern Territory and the Flinders Ranges in South Australia.

Victoria

http://museumvictoria.com.au/pages/6927/stories-in-the-stars.pdf

Stories in the Stars describes astronomical traditions from the Boorong clan. This clan was a member of the Wergaia speaking peoples in Northwest Victoria. The region is still home to other Wergaia speaking people of the Kulin nations – Wergaia, Wotjobaluk, Dja Dja Wrung. While the Boorong clan no longer exists as a separate entity, their descendants live in north-west Victoria and throughout Victoria.

The website offers examples of popular constellations interpreted as Australian animals, hunters and warriors. The focus is on the Victorian night sky but includes stars that can be easily seen in NSW. *Stories in the Stars* was produced by the Melbourne Planetarium in conjunction with the North-West Nations Aboriginal Corporation. The cultural rights to the traditions described in the show are held by the North-West Nations. *Hardcopy version available, see section five.

Meteorites and general sky stories

http://www.fireballsinthesky.com.au/fact-sheets/australian-aboriginal-interpretations-night-sky/

- Begins with an interpretation of meteors and shooting stars then lists Australia wide traditional interpretations of the night sky. The resource comes with a handy glossary.
- You can download all the text as a pdf. A copy is available for you in the CSU website, see: **Australian Aboriginal Interpretations of the Night Sky.pdf**
- Click on the fact sheet titled: **Aboriginal and scientific views of Kandimalal, Wolfe Creek Crater**. An introductory text explaining Kandimalal: Western Australia's spectacular meteorite crater opens followed by an exhibition video that explores Aboriginal and scientific views of this 300,000+ years old meteorite crater, located in the remote East Kimberley of Western Australia. Aboriginal Elders Jack Jugarie and Stan Brumby share some of their knowledge about the crater, whilst scientific knowledge about the crater is also examined. Length is 8 mins 35 secs. Indigenous perspectives start around the 3-minute mark.

Section two – YouTube videos, CSU videos

Star Stories of the Dreaming: a Documentary (Trailer)
// **Australian Aboriginal Astronomy**

TRAILER to the ground-breaking documentary ... coming soon

Euahlayi Lawman and Knowledge Holder, Ghillar Michael Anderson shares some of the ancient wisdoms of his Peoples' connection to the universe. He also speaks with a leading astrophysicist, Professor Ray Norris, as they compare the similarities between astrophysics and Stories older than time itself. Based on research by Robert Fuller.

Location northwest NSW – north of Goodooga.

Filmed by Ellie Gilbert
Researcher: Robert Fuller
Starring: Ghillar Michael Anderson and Ray Norris

Before Galileo: ABC Message Stick. Published on 10 May 2015
https://www.youtube.com/watch?v=4HgloElAoNM&feature=youtu.be

Before Galileo, ABC Message Stick Episode, featuring Yidumduma Bill Harney. This program from 2009 looks at the ways in which western science intersects with Aboriginal Cosmology, leading us to a deeper understanding of the night sky, gained by learning the practical pointers of the constellations and the guiding spirits that occupy the dark nebulae in between. Used by the YDP Dreaming Project with permission of ABC TV. For a full transcript go to http://ydproject.com/index.php?cID=375

Emu Dreaming Song. 7 minutes 46 sec. https://www.youtube.com/watch?v=yDK1s5kc7nk

This 7:46 min clip features a song written by elders and youth from Lajamanu Northern Territory. The song runs almost the entire time in conjunction with some narrative about the Emu in the sky and ceremonies conducted around it. Note: some of the narrative is inaudible probably due to a problem with the recording microphone.

The story of Pleiades by Aunty Gloria

This video is parked on a secure iCloud site; please contact your Future Moves coordinator for access.

Aunty Gloria gives a 10-minute account of her connection to the constellation Pleiades and a dreamtime story about its creation.

Dreamtime in Albury district

This video is parked on a secure iCloud site; please contact your Future Moves coordinator for access.

Leonie Mackintosh gives a talk about the local traditions and creation stories.

Through our Eyes – Dhinawan "Emu" in the sky with Ben Flick
https://www.youtube.com/watch?v=LzFYFutiwoA

Published on 24 March 2014, Ben Flick, an Aboriginal man from the Kamilaroi language group of north-western NSW, explains a creation story passed down to him regarding **'the emu in the sky**'. Astronomy is used to identify the correct time of the year to collect emu eggs.

Academic Professor Ray Norris discusses Aboriginal astronomy
https://www.youtube.com/watch?v=DTSjcPH9FGo

This video is a 3 and a half min talk about Aboriginal astronomy. Professor Ray Norris is based at the CSIRO Astronomy & Space Science in Sydney, Australia.

The Story of the Southern Cross
https://www.youtube.com/watch?v=OHCJuGlN91s

Very good sky story about the Southern Cross, runs for 10 minutes

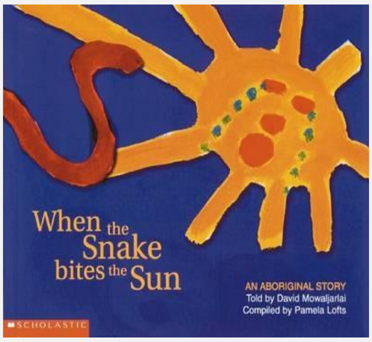
How the Moon was made
https://www.youtube.com/watch?feature=player_detailpage&v=C9BBZz9qSvE

Runs for 2 mins 30 secs. A short, animated Dreamtime creation story by Cloud skipper.

When Giant Fish Leaves the Sky
http://indigitube.com.au/culture/item/1802

Indigi tube video. This resource gives a comprehensive account of the Astronomical knowledge of the Boorong Clan of south East Australia. The story starts at 6 mins 15 seconds.

Section three – A short selection of books



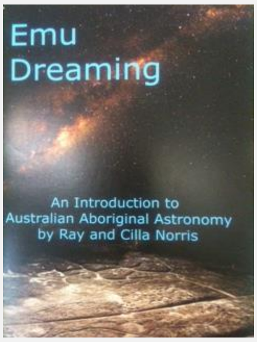
When the Snake bites the Sun

Published in: Australia, 31 March 2004

This book is based on a story told by David Mowaljarlai of the Ngarinyin people to Aboriginal children living in the Kimberly, Western Australia. The illustrations are adapted from their paintings of the story.

Publisher: Scholastic Australia

ISBN: 1865046280

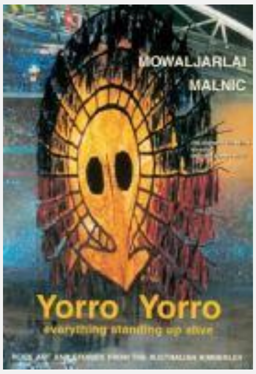


Emu Dreaming: An introduction to Australian Aboriginal Astronomy

Author: Ray and Cilla Norris

Published by: Emu Dreaming, Sydney, Australia, 2009

ISBN: 978-0-9806570-0-5

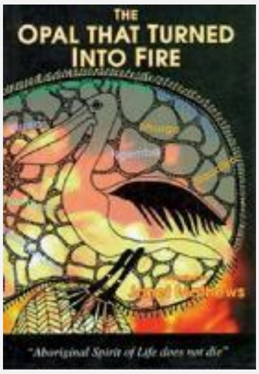


Yorro Yorro: everything standing up alive: spirit of the Kimberley

Author: Mowalijarlai, David, ca. 1928-

Publication Date: 2001

ISBN: 9781875641727



The Opal that turned into fire: and other stories from the Wangkumara

Author: Mathews, Janet

Publication Date: 1994

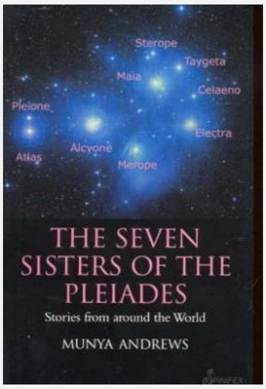
ISBN: 978187564113

Uluru and Kata Tjuta: the ultimate guide

Author: Coon, Robert

Publication Date: 2011

ISBN 9780980562958



The Seven Sisters of the Pleiades: Stories from around the World

Author [Munya Andrews]

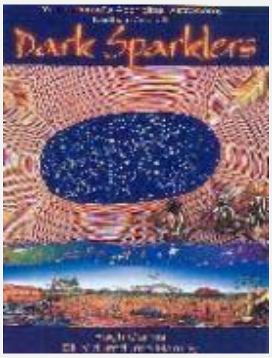
Publisher: Spinifex Press

ISBN: 9781876756451

Stars over Tyrrell: the night sky legacy of the Boorong

Author: Morieson, John

Publication Date: 2002



Dark sparklers: Yidumduma's Wardaman Aboriginal astronomy: night skies Northern Australia

Author: Cairns, Hugh (Hugh Campbell)

Publication Date: 2004

ISBN: 9780975090800

Indig Readers have a great website: http://www.indijreaders.com.au/

Two titles specifically are:

Southern Cross

by Beryl Philip-Carmichael and Fern Martins

ISBN: 978 0 9872472 2 3

Guwanyi Nura 'Telling about country'

A retell by class 6, Kamaroi school and Kim Gamble.

Authors featured in the book are: Beryl Philip-Carmichael, Raymond Davison, Jan Davison, Fay Nelson, Noelene Holten, Jenny Alcock, Cathy Pearsall and Margy Pitt.

Section four – hardcopy resources for a class that may not have access to multiple online computers

ABC Dust Echoes

There are 12 Dust Echoes stories. The three listed here are specifically related to the night sky. Copies of the documents can be downloaded on the CSU Sky Stories Project site in which this document sits or http://www.abc.net.au/dustechoes and select *study guides*. The colourful documents contain a Teacher's guide, student reading, quiz's and worksheets.

Dust Echoes - Moon Man: This story is a creation myth that tells us about the origin of the moon and its monthly cycle.

Dust Echoes - The Morning Star: This story is about how rituals following a death in the tribe are followed and how the rising morning star signifies the cycle of life.

Dust Echoes - Namorrodor: The main theme of this story is to beware of dangers at night around the campfire. The presence of Namorrodor, a flying serpent and a man-eater, is signalled by a shooting star in the night sky.

The Story of Wuriunpranilli the Sun woman: Short one-page story about the Sun travelling across the sky. Basic worksheet. A year 5/6 class in the central West of NSW used the basis of this story in 2014 to create a play.

Stories in the Stars: the night sky of the Boorong people. The Stories in the Stars explores the way an Indigenous Australian culture describes constellations in the southern skies. This is the hardcopy version, the online version can be found at http://museumvictoria.com.au/pages/6927/stories-in-the-stars.pdf. The document provides teacher notes, background information, Indigenous interpretations of constellations, a fun "Make your own planispheres" and some handy suggestions to extend learning.

Section five – Audio

https://audioboom.com/boos/2852369-audio-first-nations-astronomy#t=3m9s

An interview with Duane Hamacher Australian Society of Indigenous Astronomy

ABC Radio National Counterpoint 2 February 2015
Presented by Amanda Vanstone

Section six – Teacher reading

Australian Aboriginal Interpretations of the night sky: Fireballs in the Sky. Provides a short overview of Aboriginal astronomy plus a handy glossary.

A comprehensive list of books, articles, Teaching resources. Also includes information on Maori astronomy, Native American, Mayan and Inca astronomy.

http://members.ozemail.com.au/~mmichie/astronomy.htm Note: Some links do not work or are already noted in the resources provided above. The reading lists are very good.

Appendix U: Lesson plan ideas

Sky Stories Program – The Murray Cod Story

Unit Title: Sky Stories Program	Stage: 5-8	Duration: Optional – approximately 4 weeks
Lesson focus: Introduce students to the concept of Aboriginal astronomy. Engage with Indigenous perspectives and learning outcomes that map to the National Curriculum.		
Teacher information: Despite distinct regional differences, the central characteristic linking Indigenous culture throughout Australia is the complex and timeless spiritual reality known as The Dreaming (B. Edwards, 1998; Kerwin, 2010; Welch, n.d.). According to Magin (2005) the Dreaming includes, and is connected to, all aspects of Aboriginal life including "the Ancestral Beings, the land, the sea, humans, fauna, flora and natural phenomena ..."(p. 6). One particular aspect related to the Dreaming is the sacred relationship to the land which forms an integral part of Aboriginal spiritual, ceremonial and economic life (Goodall, 1996; Partington, 1998). Acting as ancient custodians, Indigenous Australians occupy territories that have inextricable links to their unique languages, cultural practices and traditions (Welch, n.d.). Connected intrinsically with the terrestrial landscape is the celestial night sky. Celestial observations translated into Dreaming mythologies, seasonal calendars and navigational aids have been passed down through oral traditions, imagery and geographic features for at least forty thousand years (Clarke, 2009; Norris & D.W.Hamacher, 2009). According to Bhathal (2008) "... the Aboriginal people have built an astronomical knowledge system that pervades the social fabric of their society" (p. 2). A Dreamtime narrative that links Indigenous people across the continent of Australia concerns the star cluster called the Pleiades (Johnson, 2007). For example, the people of the central desert believe that the rising of Pleiades indicates the coming of frost depicted as female kangaroos with pouches filled with ice crystals whereas in New South Wales the Gundungurra people view them as female birds pursued by the Moon (Johnson, 2007). According to Johnson (2007) "There are variants of this story in many other places across the continent, and in essence, they traverse thousands of kilometres of country as several separate narratives" (p. 4). The Wiradjuri people of central New South Wales is the largest Aboriginal language group in New South Wales and extends from Condobolin to Lithgow, Albury, and Wagga Wagga. With close similarities to their neighbours, such as the Kamilaroi, Wiradjuri culture is rich in astronomical knowledge and traditions. Ruth West, a Wiradjuri education officer and friend of the Sky Stories Project has provided a sky story that she learnt from elders living in the Wellington/Macquarie river area. The story, passed down over generations, still serves as a guide to sustainable fishing practices. The story lets fishermen know when they can fish for the Murray Cod using the rising star Sirius and the full Moon.		

Fast facts:

Murray Cod finishing spawning in spring, say by mid-October.

The Christmas Star has to be very bright to be visible low in the east just after sunset. It is most likely Sirius, the second brightest star in the sky (after the Sun). When a bright star is low down, the atmosphere acts like raindrops or a prism and splits the white light into its rainbow colours. This happens because of the turbulent nature of the atmosphere and the fact that when it is low down, we are seeing it through the equivalent of 57 thicknesses of atmosphere straight up.

The "helical rising" of Sirius can be checked using Stellarium software. Set the time to just after sunset. Wind the day time forward from, mid-October a day at a time. Watch for when Sirius first appears in the Eastern Sky. You should find that this is in Late November/Early December.

Inferences:

So, now we have a rough date for when it is ok to go fishing for the Murray Cod. This means that the Aboriginal Sky Story is a Calendrical Story. It uses the positions of the Sun and Sirius to define a time when the female cod has spawned and perhaps recovered some condition after that spawning and when it is OK to go hunting them.

Science and Technology, English and Creative Arts Outcomes, Stage 3 & 4

- see Appendix A

Online resources and books

- **See Sky Stories website for comprehensive list of resources** (link)
- Western science Murray cod: http://www.nativefish.asn.au/cod.html
- Guddhu the Murray Cod http://www.kullillaart.com.au/default.asp?PageID=48

Equipment and materials

Optional

Other people

- Community elders
- Local astronomy society
- Parents
- University personal

Overview of learning experiences

Overview of learning experiences
Introduction Students to listen to or read Sky Story text Learning experiences: Students groups to: Research and report on the bright star Sirius (what, where, stories, pictures) Research and report on other Aboriginal astronomy stories. Research and present a report/artwork on the Murray cod. Research and report on traditional food calendars. Each group to present work, teacher to combine for school community viewing. Option to present student work at a **school night observation event** Whole class: Create and present a drama/digital resource/ presentation on the traditional fisherman and their use of Sirius as a fishing guide.

The Cod Story by Ruth West

The importance of Murray cod to Aboriginal people of the Murray-Darling basin is reflected by the fact that many groups living along the Murray River made the Murray cod a central animal in their mythology, including their creation stories. Many Murray River groups believed that the wide reaches and bends of the Murray River were created by a giant Murray cod, swimming down the formerly narrow trickle to the sea, while being pursued by a dream-time hero (source: http://www.nativefish.asn.au/cod.html).

The fish was an important source of food and was managed carefully. Ruth West, a Wiradjuri Education Officer recounts the practice of traditional fisherman who used the position of the very bright star Sirius as an indicator that the Murray cod was spawning and were should not be taken. The spawning is over when Sirius is on the horizon. This meant the fisherman could take adult fish as a food source without endangering the next generation. Fishermen use the full Moon to give them light during late night fishing expeditions.

Related stories:

The Rainbow Serpent: http://www.mdba.gov.au/about-basin/basin-people/aboriginal-culture-heritage/dreamtime-stories

Ngurunderi and Ponde: http://www.murrayriver.com.au/about-the-murray/ponde-dreamtime/

Guddhu the Codfish: http://www.kullillaart.com.au/default.asp?PageID=48