Using moments of wonder in Science with pre-service teachers

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Abstract

One approach to address preservice teachers' (PSTs) often negative associations with science is through the promotion of wonder. This study investigated the impacts that engagement with science wonderings had on PSTs at a large Australian metropolitan university. Evidence from this case study indicated that engagement with wonder cultivated a culture of inquisitiveness within the PST university classroom. In particular, this approach fostered a learning culture characterised by peer discussions of scientific issues, questions and engagement in the sciences. The investigation built upon Stolberg's typologies of wonder and builds additional categories to consider when working with PSTs. Survey and classroom data provided insights for participant perceptions with regard to wonder, which had direct implications for its use as a pedagogical tool.

Introduction

There is widespread concern in government, industry and education sectors that science education in Australia is in a state of crisis (Tytler, 2007). Tackling many of the global, national and local challenges will require a workforce skilled in science-related disciplines, but negative student attitudes is a crucial element contributing towards a concerning trend in the diminishing proportion of students in post-compulsory science-related study, particularly in the enabling sciences such as Chemistry and Physics (Lyons, 2006).

While addressing the perceived systemic weaknesses associated with science education in Australia is complex, the chronic under-teaching of science in primary schools is viewed by many as an important element of reform (Cooper, Kenny & Fraser, 2012; Tytler, 2007). Many primary teachers avoid teaching science (Appleton, 2003; Tytler, 2007) averaging 41 minutes or 2.7% of teaching time each week (Angus et al., 2004). Likewise, a more recent study suggests that nationally the average total teaching time is 2% each week (Australian Science Teachers Association, 2014). Current and future teachers are at the centre of any attempt to improve science education, but as is the case for many of their in-service counterparts, primary pre-service teachers (shortened to PSTs herein on) generally lack science content knowledge and have limited confidence to teach science (Cooper, Kenny & Fraser, 2012). This is a salient factor in the under-teaching of science in primary schools because many PSTs have limited opportunity to observe experienced teachers modelling effective science teaching pedagogy during their teacher practicum (Kenny, 2012; Kenny et al., 2014). It is essential to address these oft unfavourable views PSTs' harbour in regards to their confidence and ability to teach science in order to improve science education in Australia.

Positively impacting PSTs’ perceptions of Science

Addressing the oft inadequacies of PSTs’ experiences of teaching science on their practicum is a complex problem beyond the scope of this article; however, we posit that a place to begin is to positively impact PST's perception of science and scientific thinking in order to lessen the distance they envision between themselves and Science. Considering the typical experiences of PSTs in the practicum part of their degree, it is especially crucial that the experiences in the coursework component of their degree are effective in promoting change in the way students both perceive the sciences and the teaching of it. We were informed by Schibeci (2009) regarding the importance of stakeholders to re-think science beyond merely a discipline of confusing, complex content toward one of excitement, imagination, and possibility. Future teachers, particularly those with negative views of their ability in science, often articulate a desire to teach children in more effective and engaging ways then they themselves were taught science in primary school (Gilbert, 2009). Creating positive experiences and attitudes for future teachers is essential to alleviate the crisis of interest and facilitate engagement with science content (Tytler, 2007). The question becomes how might we go about reversing years of less than favourable experiences of Science. One approach to addressing these associations of science as disconnected to their lives, and positively impact PST's lack of confidence to teach science may be on promoting students' desire to understand the world around them by promoting wonder (Milne, 2010). As part of an attempt to positively impact PST's perceptions, a sense of wonder in the sciences is accepted as one effective way of promoting PSTs' interest in Science. Consequently, this study investigated pedagogical strategies that may build PSTs' interest in Science.

Wonder and the Sciences

In order to discuss how this study aimed to promote moments of wonder, it is necessary to explore the ontology of how wonder is defined within the scope of this study.

The beauty and power of wonder lies in this direct connection to aesthetics and emotion (Stolberg, 2008; Zembylas, 2007). Hadzigeorgiou (2012) contended there are key attributes that are unique to wonder and wondering, in particular that there exists a distinct separation between wonder and curiosity. Curiosity is the drive to investigate or study something while wonder is a state of mind or feeling. Moreover, wonder has an aesthetic dimension, which can be totally absent from curiosity. This connection to emotion is often expressed when scientists describe the role of wonder in their work and the contemplative notions that discovery brings. It is this connection to the emotive that distances wonder from that of curiosity. It is this awareness of beauty and admiration, which are steeped in the emotive realm that ultimately provides the separation between wonder and curiosity. These notions of wonder often do not make into the pedagogic practice of primary classrooms nor are they often expressed in teacher preparation (Gilbert, 2013). Hadzigeorgiou (2012) argued that, when building pedagogical approaches, steeped in wonder, students must have a clearly developed awareness:

- that conceptualizes understanding as incomplete, where there is always more to learn;
- for the multiple connections across and between scientific concepts to be considered;
- regarding the beauty of the natural world and scientific phenomena.

The key here is to hold school-based science experiences to a similar what many scientists describe as the driving force in their professional science careers and discovery efforts.

There is no shortage of description of wonder within professional science circles from Rachel Carson, Albert Einstein as well as a new generation of scientists clamouring to interest a broader audience in science such as BBC personality and physicist Brian Cox. He advocates that a healthy sense of wonder is not only essential to interest others but is the main driving force feeding even the most senior scientists to better understand the world and remarkable phenomena within it. We see similar insights from Silverman (1989) who stated that… "the beginning of science is wonder, and in my view, the fostering of that wonder is the paramount task of science education at all levels of study" (p.44). These scientists remind us of the importance of not losing sight of what is most important in engaging in the sciences. The goals of this project are clearly an effort to rekindle PSTs connection to wonder and the beauty of the unknown. Consequently, we are trying to articulate PSTs' emotional engagement with the sciences and their responses to utilising wonder to drive pedagogy.

Wonder as science pedagogy

Researchers, over the last decade, have clearly argued for the innate ability of children to wonder about the natural phenomena they encounter and experience on a daily basis (Hadzigeorgiou, 2005; Howes, 2002; Hurd, 2002, Girod, 2008). Schools work to homogenise student thinking often leading older children to distance themselves from the fanciful notions like wonder and imagination (Leafgren, 2009) and often do not make important connections between science and students' wonderings (Gilbert 2013). In addition, Leafgren (2009) argued that excellent teaching, as envisioned by the authors as inspiring to children, often falls outside the realm of quiet, orderly and predictable practice that has become synonymous with 'good teaching'.

We argue, however, that wonder is not just for children. For many scientists, collecting new sets of data or envisioning new problems can often lead to notions of excitement and wonder that we would often reserve solely for children. Science itself is filled with findings celebrated with child-like enthusiasm, no matter the age of the scientist. Our underlying hypothesis is that promoting wonder would provide benefits for all PSTs, but particularly those that have negative perceptions of science. The aesthetic quality of investigating science with wonder provides the necessary connection between the student and the scientific ideas that are being investigated (Girod ’ Wong, 2002; Wickman, 2006). "For this reason, the aesthetic element should also be sought in that personal experience of doing science, and hence linked to such notions as mystery, awe, wonder, imagination, inspiration" (Hadzigeorgiou, 2005, p. 41). These notions speak to rather an intense need to know and understand (Gilbert, 2011). It is this need to know that we are trying reignite in our PSTs. These emotional connections to science content serve are essential to engage PSTs and connect science content to their everyday experiences (Stolberg, 2008). Zemblyas (2007) argues this emotional engagement must be built into our classroom approaches and drive our pedagogy. The essential importance here is to keep in mind that, as educators, we must trigger PSTs’ connection with the natural world in order to engage their interest in science through "wonder, questioning, and curiosity about how the world operates" (Feist, 2012, p. 773). This certainly speaks to the problems we face considering the waning interest in science across various areas of education.

The goals of this project represent an effort to generate interest in science and explore the degree to which wonder frameworks can offer in this regard. Furthermore, we are directly responding to Stolberg's (2008) call for researchers to develop strategies steep in wonder:

… it is clear that both teachers and pupils need to be made more aware of the feelings wonder can engender. Pedagogical strategies need to be developed so that teachers can facilitate pupils to reflect on the possible meanings of the wonder, so helping them to develop a mature scientific voice (p. 1963).

Similarly, Hadzigeorgiou (2012) asserted that when utilising 'wonder' as a pedagogical framework we must consider: the tentative nature of knowledge, the willingness to consider "unexpected connections between phenomena and ideas" (p.989) and an appreciation for the beauty of the natural world. Utilising these frameworks, the authors of this study endeavoured to engage adult science learners using a teaching strategy where PSTs were encouraged to ask science questions they had always wondered about. The following is an attempt to address the crisis of interest that currently faces science education in addition to answering Stolberg's charge to develop 'pedagogical strategies' that help students utilise their special connections to wonder.

Research questions

1. Does the use of a weekly wonder wall in a Bachelor of Education (BEd) Science unit promote wonder amongst primary preservice teachers (PSTs)?
2. What is the nature and sophistication of PST's wonders regarding science content and what might that tell us about their conceptualisations of science?
3. What are the possibilities and implications for utilising pedagogical strategies steeped in wonder?

Methodology

Case Study

We chose to incorporate a case-study analysis to delve into the impacts of wonder on PST perceptions of science related content because as Baxter and Jack (2008) argued, case study is sensitive to the essential role context plays within the study. More specifically, context itself is an essential aspect of the study where PST's involved in a university setting make up an important factor framing all the activities within the project. We further delineated this approach as an instrumental case study (Stake, 2000) where the question regarding the impact of wonder on perceptions of science was the paramount goal as opposed to understanding the case itself. Case study also offers flexibility for our interpretivist stance regarding meaning and behaviour (Creswell, 2005) and the associated subjectivity regarding social activity and interactions (Denscombe, 2007).

Context, Participants and Study's Data Artefacts

Each week for weeks 2-6 of a semester, third year primary PSTs in a Science investigation unit were asked to think of science questions they wondered about, write them on a Post-it-Notes (PIN) and stick them onto the tutorial 'wonderwall'(Appendix 5). The instructions were intentionally ambiguous in order to not influence the kinds of questions PSTs posed. At the conclusion of the 5 minutes allotted for students to write down their questions and stick it on the wonder wall, PINs were removed after class from the wonder wall by the researcher. PSTs were assured that it was a safe environment to ask any science-related question and students were reminded at the duration of each class to think about a wonder wall question they could write down for the upcoming week. The anonymity of any questions posted on the wonder wall was emphasised which may have catered for students who were too afraid to ask questions in front of their peers and as a strategy to elicit students' 'genuine wonder'. The researcher openly discussed the importance of not writing a question because they felt pressured to do so. Considering the importance of students' 'genuine wonder', the teacher/researcher explicitly gave students the option of posting their note on the wonder wall or keeping it as an individual exercise. There were students who did not wish for their questions to be read by their peers or analysed in this study and the researcher discerningly respected students' wishes. Subsequently, these PIN questions were thematically coded. Each question was transcribed with a unique identifier: (note_number). The process of analysis will be discussed shortly. Additionally, the researcher kept a reflective journal writing down his perceptions of the process and observations. Each week, the researcher wrote approximately a page reflecting on the questions posed by students in an attempt to notice patterns, trends and/or make observations. The researcher also wrote reflections during the thematic coding process. Each reflection was assigned a unique identifer: (trddmmyyyy). Reflective journals provide a valid method for researching teaching and learning (Phelps, 2005). Journals have the potential to provide key insights that can be difficult to document in other ways (Creswell, 2005). They provide an opportunity to challenge individuals to reflect on new ideas, concepts and theories and to engage in action (Phelps, 2005). Following completion of the Science unit, students were asked to fill in an online survey instrument as shown in Appendix 6. The population of interest in this study was third year primary PSTs . In total, the population size was n=52. Following several reminder emails about this study, 40% of students (n=21) completed the online survey. While gender information was not elicited from survey participates, there is considerable female gender bias in the population (87% (n=44). At the time of data collection, participates were in the final weeks of their second 12.5% primary science unit in their course.

The data artefacts of this project include 1) the PIN questions posed by PSTs, 2) reflective journal writing by the teacher/researcher and 3) the online survey sent to students following the completion of the Science unit. Three data sources (students' questions, reflective journal, and student survey) are used in this project to achieve the aims of this research project. Triangulation of these data (Patton, 2001) facilitated deeper understanding of the research questions posed in this study. The three data sources are used interchangeably, in a non-linear fashion, considered most effective to answer the research questions posed. In order to give the reader a general sense of the confidence levels of PSTs to teach Science in this study, it is necessary to examine the students' reported confidence to teach different curriculum areas.

Students' Reported Confidence to Teach Curriculum Area

Table I. Mean rank of Subjects ordered according to students' confidence to teach curriculum area

Subject	Mean
English	2.05
Maths	2.32
Social Sciences	3.38
Sciences	3.71
Digital Technologies	4.33
The Arts	4.90

Note: 5 point scale. Lower score indicates higher reported confidence.

The data from the online survey as indicated in Table 1, perhaps not surprisingly, participants reported a relatively low level of confidence to teach Science. Almost a quarter of the sample (24%) ranked Science as their least confident subject to teach. Compared to the mean average of English (M=2.05), students reported significantly less confidence to teach Science (M=3.71, $p<.05$). These results indicate similar results to a study asking a similar question with a larger sample (>150) (Cooper, Kenny & Fraser, 2012) and is perhaps representative of the generally low level of confidence in the cohort to teach Science.

Data Analysis

Stolberg's (2008) typology of wonder framed the overarching analysis of student questions/wonderments. However, we also kept our minds open to new possibilities for what might emerge from the data itself as we coded and analysed data sets

(Strauss & Corbin, 1998). This study adopted Stolberg's (2008) classification of wonder but expands and defines different kinds of wonder as stated below:

1. Physical wonder: Non- human related Phenomena or processes found in Nature are the stimuli of the wonderment;
2. Personal wonder: Human beings or their work are the stimuli of the wonderment;
3. Metaphysical wonder: Which is prompted by any interaction, but the wonder evoked goes beyond a reflection on the original stimulus.

This approach and the willingness to be open to new ideas was predicated on the existence of multiple realities and trying to make sense of human behaviour, thoughts and interactions are often only one aspect of multi-layered issue (Ladson-Billings, 1994). Consequently, we endeavoured to incorporate differing and creative sets of data to both create and sustain credibility (Patton, 1990). Following analysis of PSTs' questions/wonderments using Stolberg's (2008) typology of wonder, the analysis will widen to discuss more generally about the potential implications of using the wonder wall in a university teaching environment.

Results and Discussion

Thematic analysis of PSTs' wonders

As discussed, each week for four weeks of a semester, third year primary PSTs were asked to think of science questions they wondered about, write them down and stick them onto the class wonderwall. Subsequently, Stolberg's framework was used to place students' wonders into thematic categories. During the analysis, it was clear that in addition to Stolberg's typologies, Pedagogical wonders manifested into its own distinct theme. A pedagogical wonder is defined in this paper as questions where science pedagogical perspectives, teaching and learning are stimuli of the wonderment. Hence, the first section of these findings examines students' Physical, Personal, Metaphysical and Pedagogical wonder.

As discussed, the researcher kept a reflective journal writing down his perceptions and observations students as they are asked to state their wonder by writing a science-related question. Moreover, students were asked to fill in an online survey following the completion of the Science unit. In sum, students asked a total of (n=72) different questions.

Table II. Classification of PSTs' wonders

Type of Wonder	n	≈%
Physical	31	43
Personal	28	37
Metaphysical	6	8
Pedagogical	8	11

Note: All Questions shown in Appendix 1, 2, 3 & 4

Physical wonder

As shown in Table 2, 43% questions related to physical wonder. These are the questions related to wonderment regarding non- human related phenomena or processes found in Nature. As shown below, the wonders ranged in complexity from Why doesn't water and oil mix? (note_66) to Are we alone in the universe? Is there any other planets we can live on? (note_72). 43% of all unique questions were classified in into nature wonder. Of the 31 wonder questions in this category, 10 questions (31%) could be classified as having strong links and themes to celestial objects and astronomy, for example:

- What is a black hole? (note_64)
- Why is there no wind in space? (note_2)
- How does the moon control the ocean? I don't get it…. (note_74)
- What is beyond the universe? Does it go forever? (note_38)
- Why is there no wind in space? (note_2)

"The number of astronomy-related questions makes me think that it is a particularly good way to get PSTs excited about Science….that there is a strong innate need for humans to make sense of their place and the formation of our universe… there is something uniquely special about astronomy that manages to motivate even the most unmotivated student to learn about it" (tr11062015). These data suggest that university teaching programs may be able to tap into the apparent high levels of wonder relating to Earth and space sciences by focusing on such concepts (e.g. stars, galaxies, planets). Tapping into the sciences that excite and motivate PSTs should be viewed as a priority for science educators, as these moments may act as the catalyst for further learning of Science. PSTs need opportunities to develop their

understanding of concepts in contemporary astronomy with particular emphasis on the links between knowledge and practical investigations, including the utilisation of information technology (Watters ’ Ginns, 2000). In addition, science educators need to be explicitly modelling hands-on, student-centred pedagogies that compliment such knowledge.

Personal wonder

The results indicated that 37% (Table 2) of questions related to Personal wonder. In this category, human beings or their work are the stimuli of the wonderment. This category was rather difficult to categorise because a wonder such as *What is consciousness?* (note_24) could be interpreted as a possible wonder about the physiology and anatomical elements that underpin what a medical professional may define as consciousness verses, for example, a sociologist’s or a philosopher's definition of this phenomena. Students had a range of questions about how humans have developed or manipulated machines/materials/symbols to overcome problems or barriers they have faced, for example:

- Who invented the term ‘science’? (note_43)
- Do eskimos actually live in igloos? If so, how they keep warm/survive? (note_16)
- How does a soda stream carbonate water? (note_65)
- How is plastic made? (note_20)
- Humans contribute to the world, but do we contribute to the universe? (note_7)

While the questions in the category above indicate some interest in exploring the human endeavour of science and solutions to the barriers faced by mankind, it was clear that many of the questions in this category focused on the different biological questions about humans. (n=18/67%) of the questions in this section were strongly related to the structure and function of the human body. For example:

- Why do people have different coloured eyes? (note_8)
- Why do we dream? (note_29)
- What is consciousness? (note_24)
- Why do hiccups happen? What are they? (note_35)
- Why does each person’s hair stop growing at a certain length? (note_71)
- Are growing pains real things? (note_56)

These data suggest that: *"University teaching programs may be able to tap into the apparent levels of wonder in relation to the human body by planning learning tasks exploring the different physiology and anatomy of the human body"* (tr19062015). As many primary education cohorts have a gender bias towards females, it is interesting to note that, girls' out-of-school experiences are more commonly associated with biology, such as watching birds or planting seeds (Jones, Howe, & Rua, 2001). Conversely, boys continue to have more extracurricular experiences that are related to the physical sciences, including the use of electric toys and pulleys (Jones, Howe, & Rua, 2001). Hence, these data suggest that university teaching stakeholders may effectively use this apparently oft high level of PST wonder by exploring the biological sciences.

Metaphysical wonder

Only 8% (Table 2) questions were classified as wonderment about metaphysical phenomenon. These data strongly support the idea that many PSTs view the discipline of science from a predominately positivist paradigm. In other words, they view science as a way to uncover absolute truth, to understand the world in order to predict and control it. For example:

- When will what we know be enough? (note_17)
- Define science (note_50)
- Will we ever cure science? (note_4)
- What is the meaning of life? (note_49)
- What is science? (note_9)

These types of questions indicate the capacity of students and highlight a great opportunity for science educators to foster and promote this complexity of thought. These questions show that some students, albeit a small number, have the ability to explore such ideas in their teaching degree. From my own informal observations and anecdotal accounts, I fear that few, if any, programs effectively allow preservice teachers to explore such complex ideas in their teaching degree programs. While beyond the scope of this paper, more research needs to be done into how teaching programs foster and develop such thinking in their degree programs.

Pedagogical wonder

In what manifested into its own distinct theme, Pedagogical wonder was a salient theme underpinning PSTs' questions. Pedagogical wonder is defined here as teaching and learning perspectives and/or possibilities as the stimuli of the wonderment. As shown in Table 2, 11% (n=8) of questions involved Pedagogical wonders, for example:

- What do we say when kids ask “What does that mean?” and we don’t know? (note_3)
- What are some good resources for us as teachers to build our own science knowledge? P.S. I have no prior knowledge of any topics LOL (note_28)
- What are some ways science can relate to the average classroom curriculum? (note_14)
- What are some ways to explain the content being learned? (note_51)

“The questions certainly imply a desire to learn more about Science and how to teach it effectively. Although these questions certainly show encouraging aspirations to know more about how to teach good Science, I fear it is not presently enough.” (tr24062015).

There are two important points to make here. First, these data certainly make a case for expanding the categories of wonder from Stolberg’s original framework, particularly when working with PSTs. Second, these results arguably hint at students’ desire for the ‘secret recipe’ to teaching Science. In the hope that class will somehow enlighten students how to be effective teachers of Science. This desire by students to know the ‘secret recipe’ speaks, in part, to the systemic problems in Australian Science education.

This section of the paper concludes analysis of PSTs’ questions/wonderments. Below, the analysis widens to discuss more broadly observations made during use of the wonder wall.

Laughter and fun in the Science classroom

The following questions highlight the potential of the wonder wall to bring genuine laughter and fun into the Science classroom:

- How did life begin? Was it the chicken or the egg? (note_6)
- If we keep our eyes open during a sneeze, will our eyes fly out? (note_18)

“Every week at the conclusion of ‘wondering time’, I had a quick scan of the questions posed by students. I attempted to read out a broad spectrum of questions

covering a range of science concepts and at the beginning, questions I considered to be appropriately funny and witty in order to promote a sense of ease and comfortableness with the questioning. While not everyone took the opportunity to pose 'serious science questions', I felt that even the students who wrote a funny/witty question still contributed to the Science discussions. By this I mean that the class and I genuinely laughed at some of the questions posed and considering the PSTs' common negative attitudes/experiences/memories of learning Science, I think these moments contributed to a warm, friendly and non-threatening learning climate" (tr18062015).

From the experiences of this semester, strategies such as a wonder wall have the potential to bring fun and laughter into the Science classroom. An important consideration for university educators is the importance of laughter and fun in the Science classroom as a metaphorical cultural bridge that may be the impetus students need to see the how learning about the sciences may enrich their own lives as well as their future students.

Visible science learning culture

One of the biggest benefits of using a wonder wall may be its potential to foster and promote a visible 'science learning culture'. Science learning culture is defined here as students' discussions of scientific issues, research, asking questions and generally engaged in the sciences. This scenario is not unlike a field of scientists collaborating, communicating ideas and trying to overcome the problems they face. *"University educators know that the space allocated to science teaching is limited in teacher education programs. Seemingly modest techniques such as a weekly wonder wall may have a considerable effect on giving preservice teachers a valuable learning experience in their degree where they feel more confident to go and teach Science"* (tr23062015). The author acknowledges that it will take a lot more than a wonder wall to develop and grow the science learning culture that needs to be developed. However, a weekly wonder wall may be a step in the right direction towards promoting a vibrant and budding science learning culture.

PSTs' evaluations of the Wonder wall

Following the completion of the science unit, students were asked to anonymously report what they thought of the wonder wall initiative. A sample of 21 students completed an online survey: **PSTs confidence to ask science-related questions**.

There is evidence to suggest that PSTs may feel a strong sense of embarrassment about not knowing what some may consider being very basic science content knowledge (Van Driel, Jong & Verloop, 2002). Pedagogical strategies that give PSTs the opportunity to ask science questions without the risk of shame or embarrassment from peers or lecturers sounds appealing. The following statements infer a greater confidence to ask science questions without feeling awkward or inferior in some way:

- I liked the idea of deep thinking and encouraging questions in class-also showed that no question is stupid and it's okay to not know anything. (survey_01)
- I think it's a good idea to get students thinking about what they want to know without being judged. (survey_02)
- I feel it is a great idea to bring into the classroom. It gives the chance for everyone to ask a question without having the thought of it being a silly question. (survey_09)

Use of Wonder wall in future science teaching

Pre-service teacher education programmes are central in preparing graduates to become effective teachers equipped with the necessary pedagogical practices that will serve the needs of their future students (Cochran-Smith, Feiman-Nemser & McIntyre, 2008). Use of the wonder wall is an effective model of a constructivist-teaching strategy PSTs may implement in their future classrooms. There was evidence from the surveys that PSTs were thinking about the potential benefits of using a wonder wall with primary-aged students:

- Great learning tool, allows students who may not normally speak up [and] ask questions. / -Sparks conversation / -can be used in other subject areas.... (survey_13)
- I thought it was very effective at assessing what students know and what they would like to know. It's also an enjoyable way to do this. (survey_06)
- Great tool to use in the classroom. Good way to engage students. (survey_08)

Some possible frustrations

Although the class had approximately 10 minutes each week to discuss some of the science questions posed it was certainly not enough time to explore (or answer) students' questions with any considerable depth. This apparently frustrated some students in class:

- I like the wonder wall and have seen it on my placement previously. I would have preferred to go through some in class with some evidence. (survey_14)
- Effective if answered (survey_20)

As stated previously, the intention was never to answer all of the students' questions, rather to get them tapping into their innate curiosity and wonder. Perhaps these reported student frustrations tap into broader concepts and questions regarding the structure of education in general. What is it about how we teach science that slowly diminishes students' curiosity and wonder? If we are to have a scientifically literature community, what role does curiosity and wonder have to play? What role should curiosity and wonder have in teacher education programs?

Summary

Does the use of a weekly wonder wall in a BEd Science unit promote wonder amongst primary preservice teachers (PSTs)?

From the questions elicited, there is certainly evidence to suggest that the use of a wonder wall promoted and fostered Physical, Personal, Metaphysical and Pedagogical wonder amongst primary preservice teachers. A substantial contribution of this research is the elicitation of evidence to suggest expanding the categories of wonder from Stolberg's original framework, particularly when working with PSTs. Compared to asking in class, PSTs appeared to have a higher level of confidence to ask scientific questions during the wonder time. How much of an impact on confidence probably varies, is difficult to measure, and in any case, beyond the scope of this study. The use of the wonder wall allowed briefs moments of laughter and celebration into the Science classroom. Although these moments may seem trivial, and what some might label a waste of time, I would describe the use of the wonder wall, especially in the first few weeks, as a little 'anxiety icebreaker' for students who are probably weighed down by their negative beliefs and attitudes to Science from their experiences in school. Perhaps the most valuable impact though is how the wall helped form a visible science learning culture. A learning culture characterised by peer discussions of scientific issues, questions and engagement in the sciences. Establishing a culture of risk taking, upholding students' anonymity and expecting all to contribute set the scene for students to participate in their own little scientific community, even if they didn't know it.

What is the nature and sophistication of PST's wonders regarding science content and what might that tell us about their conceptualisations of science?

Students wondered about a wide variety of stimuli ranging from black holes to the etymology of science. 43% of students' questions were wonderment about nature with a considerable number of questions regarding celestial objects and astronomy. 37% of questions were classified as wonderment about human beings or their work. A considerable amount of these questions revolved around wonder about structures and functions of the human body. A small number of students questioned philosophical and pedagogical concepts within a scientific paradigm. Although this study was exploratory in nature, these study's findings imply that many PSTs view the discipline of science from a primarily positivist paradigm. From such a paradigm, science is merely a set of laws regarding cause and effects that can be understood if scientific methods are applied to phenomenon (Appleton, 2013). Such findings hint at PSTs' typically narrow, positivist–aligned conceptualisations of the sciences.

What are the possibilities and implications for utilising pedagogical strategies steeped in wonder?

The implications of using a wonder wall may be one modest strategy used to build PSTs' interest in Science. The use of a wonder wall appears to promote a learning environment that helps students utilise their connections to wonder. Hadzigeorgiou (2012) asserts that when utilising 'wonder' as a pedagogical framework, one must consider the tentative nature of knowledge, the willingness to consider "unexpected connections between phenomena and ideas" (p.989) and an appreciation for the beauty of the natural world. Tapping into students' curiosity and wonder may evoke a deeper aesthetic appreciation of the sciences.

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Appendices

Appendix 1: Physical wonderment

How does the moon control the ocean? I don't get it…. (note_74)

If a butterfly flaps its wings in one continent, can it really cause a hurricane in another? (note_25)

Why is there no wind in space? (note_2)

Are we alone in the universe? Is there any other planets we can live on? (note_72)

What are the chances that aliens exist? (note_5)

Can anything besides light travel at the speed of light? (note_46)

Where does wind come from? (note_33)

Why can you see stars clearer on some nights compared to other nights? (note_44)

What happens to cells that die? (note_71)

How are fireworks made into different colours? (note_11)

What is beyond the universe? Does it go forever? (note_38)

Because there are multiple ways to show retnal DNA, do people see differently depending on this? (note_62)

Which animal has the highest number of chromosomes? (note_21)

Why do the summer temperatures change every year? It was hotter last year than this year? (note_42)

How long do we have roughly until Earth is no longer inhabitable? (note_34)

Which is hotter? The centre of Earth or the Sun? (note_23)

Why doesn't water and oil mix? (note_66)

The hottest part of the day is getting later and later. Why? (note_31)

How can light be reflected, absorbed and retracted? And why is it important? (note_32)

What is the lightest element? (note_54)

What is a black hole? (note_64)

How do rockets take off in outer space planets if there is no oxygen? (Most engines mix oxygen with fuel to work) (note_37)

What is it called when something is not quite liquid and not quite solid? (note_26)

Why don't we typically have tornados/hurricanes in Victoria? (note_53)

How come some watermelons are seedless and some aren't? (note_67)

Why does the weather change so dramatically from one day to the next? (note_15)

How hot is the sun? (note_36)

How did life begin? Was it the chicken or the egg? (Post_it_note_1)

How fish gills work? (note_57)

How is glitter made? (note_12)

Do you think they will find any more elements for the periodic table? (note_47)

Appendix 2: Personal being wonder

Why do people have different coloured eyes? (note_8)

How is plastic made? (note_20)

Are growing pains real things? (note_56)

Why does skin blister? (note_19)

How do planes work? (note_13)

Do eskimos actually live in igloos? If so, how they keep warm/survive? (note_16)

Do different smells smell the same to different people? (note_69)

How does the ink stay in the pen and only comes out in contact with something? (note_58)

Why do tastebuds work differently for different people? (note_27)

Why do people have different coloured eyes? (note_8)

How does a soda stream carbonate water? (note_65)

Why do we dream? (note_29)

Who invented the term 'science'? (note_43)

We only see through what our brain interprets through our eyes…how do we know there aren't more colours that exist? (note_40)

They say English is a complex language to learn? I wonder if there are any easy languages to learn? (note_63)

How do I make curly hair stay straight permanently? (note_73)

What is consciousness? (note_24) (x2)

Why do we dream? (note_29)

Why has Pluto been classified as a planet again? (note_41)

How does a soda stream carbonate water? (note_65)

What is quantum physics? (note_59)

If we keep our eyes open during a sneeze, will our eyes fly out? (note_74)

How do different colours exist? (note_45)

How do planes work? (note_13)

If we know the science behind why people get fat, why do we eat so badly? (note_1)

Why does coffee keep me awake? (note_70) (x3)

Why do hiccups happen? What are they? (note_35)

How hot can a human body stand before having consequences? (note_75)

Why are people going to Mars? (note_48)

Why does each person's hair stop growing at a certain length? (note_71)

Are there theories that are being developed for people to walk through walls? (note_30)

Do eskimos actually live in igloos? If so, how they keep warm/survive? (note_16)

Appendix 3: Metaphysical wonder

When will what we know be enough? (note_17)

Define science (note_50)

Will we ever cure science? (note_4)

What is the meaning of life? (note_49)

What is science? (note_9)

Appendix 4: Metaphysical wonder

What do we say when kids ask "What does that mean?" and we don't know?(note_3)

What are some good resources for us as teachers to build our own science knowledge? P.S. I have no prior knowledge of any topics lol L (note_28)

Why isn't science taught as a whole different class like Music/PE? (note_39)

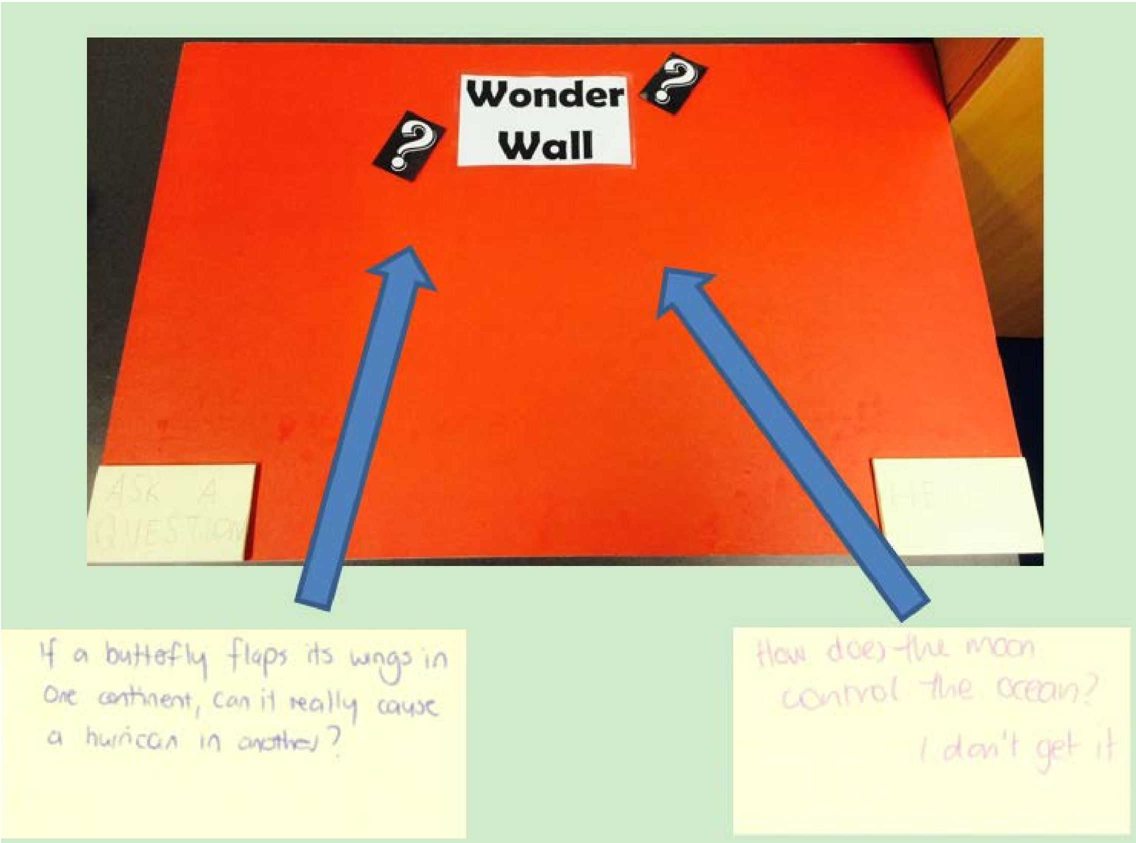
What are some ways science can relate to the average classroom curriculum (note_14)

Would it be appropriate to use Breaking Bad to engage students in chemistry? (note_10)

Why is science such a big thing for students to learn? I can't understand the meaning behind science :s (note_60)

What are some ways to explain the content being learned? (note_51)

Appendix 5: Wonder Wall Board



Appendix 6:

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT PARTICIPANT INFORMATION - Online Questionnaire

Q1. Please answer the following questions:

1-7______ I feel confident about teaching Science

Q2. What did you think of the Wonderwall?

Q3. Please list in descending order the subject area you feel most confident to teach below (the top subject will be the one you feel most confident to teach)

Most confident to teach
______ English
______ Maths
______ Science
______ Humanities and Social Science
______ The Arts
______ ICT