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# Common Alternative Astronomical Conceptions Encountered in Junior Secondary Science Classes: Why is this so?

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**Abstract**
This paper investigates students' conceptions of certain astronomical phenomena. The 1,920 participants were drawn from junior secondary science classes in four Australian educational jurisdictions. Participants completed a modified version of the Astronomy Diagnostic Test to elicit information about their knowledge and understanding of certain astronomical phenomena and to identify any alternative conceptions held by them. Results showed that students exhibited many alternative conceptions about concepts they should have covered in elementary or the first year of high school. Discussion centres on the extent to which school science takes account of the important construct of pedagogical content knowledge.

**Keywords:** Year 7-9/middle school, Research into teaching/learning, astronomy, Alternative Conceptions, Pedagogical Content Knowledge (PCK).

# Introduction

Astronomy is Australia's premier science and one that captures the interest and imagination of people from all walks of life. Australia continues to play a leading role in both radio and optical astronomy. For example, instruments such as the 2dF, AAOmega and FLAIR employing multi-fibre object spectroscopy have been developed on the Anglo-Australian Telescopes to undertake survey work and which are later adapted and built for the largest telescopes in the world. The Australia Telescope National Facility, which includes the Compact Array at Narrabri and the famous Parkes Radio Telescope, provides unparalleled views of the southern sky at radio wavelengths. Australia is one of the remaining two sites for the location of the Square Kilometre Array that will provide terabytes of data per second on the early universe. In Australia, astronomy is well represented in all State and Territory Science and Technology Syllabuses in both the primary (elementary) and high school years. Although astronomy is a premier science, it is not well taught as demonstrated by Stahly, Krockover, & Shepardson (1999), Taylor (1996) and Trundle, Atwood, & Christopher (2002). Specifically, numerous alternative explanations are promulgated by students, their teachers and other adults about common astronomical phenomena.

More generally, research in science education both nationally and internationally has revealed that students do not always accurately learn scientific information (e.g., Odom & Barrow 2007; Osborne & Freyberg 1985; Talanquer 2002; Wandersee, Mintzes, & Novak 1994). Such investigations have shown that one major reason for this happening is that students already possess their own conceptions based on their experiences, and which differ in many ways to the accepted views of science. These alternative explanations are seldom challenged in the science they experience at school.

In experiencing science at school, students' prior knowledge interacts with the content introduced by teachers in the classroom. Such an interaction can result in a number of mixed mental model outcomes. Student models range from students: maintaining their existing beliefs unaltered; using the new model to explain other scientific phenomena different from that which the explanation/concept was intended to apply; to accepting the new scientific explanation (e.g., Chinn & Brewer 1993; Fensham, Gunstone, & White 1994). In intermediate cases, students continue to possess numerous explanations about various scientific phenomena at variance with the currently accepted scientific beliefs, e.g., the Sun orbits the Earth daily (Philips 1991); condensation on the outside of a glass of icy water is caused by the water going through the glass (Gilbert, Osborne, & Fensham 1982) . Changing students' conceptions is not easy because these have been constructed to explain what they have observed. In addition, the conception has not been successfully challenged to the extent that they seek a better, more scientific, explanation.

Different researchers have labelled the constructs students possess that are alternative to the accepted science beliefs as misconceptions, preconceptions, children's science, alternative frameworks, non-scientific views, erroneous notions, private versions of science, synthetic mental models, unfounded beliefs and naïve notions (e.g., Finegold & Pundak 1990; Sneider & Ohadi 1998; Vosniadou 1991; Wandersee, Mintzes, & Novak 1994). The preferred term used by many researchers (e.g., Abimbola 1988; Gilbert & Swift 1985) is *alternative conception* because "it refers to experience-based explanations constructed by a learner to make a range of natural phenomena and objects intelligible, but it also confers intellectual respect on the learner who holds those ideas" (Wandersee, Mintzes, & Novak 1994, 178). In contrast, the previously favoured term "misconception" implies the learner's construct is wrong. Consequently, the term "alternative conception" will be used in this paper to refer to the constructs learners possess that are alternative to the currently accepted scientific beliefs.

Research on students' alternative conceptions about astronomical phenomena has appeared in the literature for more than fifty years (e.g., Haupt 1948; Kuethe 1963; Nussbaum & Novak 1976;

Sneider & Pulos 1983; Stahly, Krockover, & Shepardson 1999; Trundle, Atwood, & Christopher 2006). Many studies have focussed on individuals' conceptual understanding of, and alternative conceptions about, various astronomical phenomena such as: the day and night cycle (e.g., Atwood & Atwood 1995; Byrne 2001; Dunlop 2000; Fleer 1997); the Moon and its phases (e.g., Barnett & Morran 2002 Cohen & Kagan 1979; Haupt 1948, 1950; Stahly, Krockover, & Shepardson 1999; Trundle, Atwood, & Christopher 2006); the seasons (e.g., Atwood & Atwood 1996; Osborne et al. 1994; Parker & Heywood 1998; Sharp 1996); and, the shape of Earth and its position in space (e.g., Baxter 1989; Mali & Howe 1979; Samarpungavan, Vosniadou & Brewer 1996). Such research has ascertained that not only students but also pre-service teachers and teachers hold non-scientific views about these phenomena (e.g., Jones, Lynch, & Reesink 1987; Lightman & Sadler 1993; Nussbaum 1985; Sharp 1996; Skamp 1998; Taylor 1996). For example, children and adults (including teachers) think day and night are caused by the Sun going around the Earth, the phases of the Moon are caused by a shadow from the Earth and seasons are caused by the Earth's distance from the Sun. Often, traditional science instruction takes no account of students' current conceptions and has little impact on their alternative conceptions (Sadler 1998; Zirbel 2004). Therefore, it is critically important that science teachers have an understanding of, and know how to deal with, the alternative conceptions that students bring to the classroom.

One key construct that has been around for over 20 years, pedagogical content knowledge, represents a framework to help teachers think about the role students' alternative conceptions can play in the educative process. Pedagogical content knowledge (PCK), conceptualised by Shulman (1986), refers to the knowledge that teachers draw upon and which is specific to a subject or content area. That is to say, the PCK required to teach astronomy is different from that which is required for biology. Thus, PCK encompasses an understanding of what makes the learning of a particular topic uncomplicated or complicated and knowledge of the conceptions and alternative conceptions that students of different ages might hold in relation to the topics taught (Shulman 1986). Grossman (1990, 8-9), extended this definition of PCK and describes four central components: "knowledge and beliefs about the purposes of teaching a subject at different grade levels"; "knowledge of students' understanding, conceptions, and misconceptions of particular topics in a subject matter"; "curricular knowledge which includes knowledge of curriculum materials available for teaching particular subject matter, as well as knowledge about both the horizontal and vertical curricula for a subject"; and, "knowledge of instructional strategies and representations for teaching particular topics".

Researchers, such as Cochran, DeRuiter, & King (1993), argued that the term "knowledge" in the above definition did not emphasise strongly enough the dynamic nature of PCK and extended the concept to be one of "pedagogical content knowing" (PCKg). Their interpretation highlights the importance of the integration of the four components of PCK, and adds a fifth, the environmental context of learning. That is to say, the components should not be acquired individually and pieced together by teachers. Rather, they should be acquired simultaneously in an integrated fashion.

Fernández-Balboa & Stiehl (1995) add a sixth component involving the teacher's knowledge about one's own purposes for teaching that is concerned with the teacher's "belief system" and which influences their own construct of what constitutes PCK. They also claimed that effective PCK did not simply involve acquiring knowledge of each of the components but rather one's ability to integrate the components. Nonetheless, the concept of PCK is central to teachers' work (Marks 1990).

Knowledge of students' conceptions and alternative conceptions of particular topics in a subject is one key component, identified in all of the PCK definitions above, that must be taken into account for effective science instruction to occur. Moreover, in Australia, the astronomy concepts that are covered in primary school science are repeated at the junior secondary level. For example, the primary and junior secondary science curriculum documents of all Australian States and Territories for grades 3 and 4 and grades 7 or 8 cover the same concepts on the causes of day and night, the phases of the Moon and the seasons. One would, therefore, anticipate that as students progress to higher grade levels they would possess fewer alternative conceptions about these phenomena.

The purpose of this paper is thus fourfold. First, we investigate the conceptions held by Year 7, 8 and 9 students (first three years of high school) of certain astronomical phenomena including day and night, lunar phases, seasons, the apparent movement of the Sun, and, the orbits of the Earth and Moon about the Sun. Second, we identify the alternative astronomical conceptions held by students. Third, in the discussion, determinations are made on the extent to which the teaching/learning experiences in school science have been successful in addressing students' alternative conceptions and finally, the extent to which school science appears to take account of the important construct of pedagogical content knowledge.

# Method

The study from which the present results are drawn took place in four educational jurisdictions located on the eastern side of Australia: the Australian Capital Territory, New South Wales, Queensland and Victoria. The 30 schools involved in the study were drawn from both the public and private educational sectors. The participants were 1920 junior secondary students of whom 1217 were drawn from Grade 7, 505 from Grade 8 and 198 from the Grade 9. The research was conducted in the middle of the academic year by which time the Year 7 students would have covered the curriculum content in primary school and the Year 8 and 9 students would have repeated the similar material in Year 7. It is mandatory to cover the content on the Earth and Space. The efficacy of the curriculum coverage is problematic for a number of reasons not the least to which is teacher expertise.

The original Astronomy Diagnostic Test (CAER 1999, 2002) was developed for undergraduate introductory astronomy courses in the Northern Hemisphere and comprised of 21 multiple-choice items to assess students' knowledge and understanding of certain astronomical phenomena (Hufnagel et al. 2000). The instrument used in this research has been adapted from the original Astronomy Diagnostic Test Version 2.0 (CAER 1999) with a number of changes being made to render it appropriate for high school students in the Southern Hemisphere.

The Astronomy Diagnostic Test was used to collect information on students' knowledge and understanding of astronomical phenomena and to identify their alternative conceptions. Changes were made to five items. Item 1 (Sun at midday) was modified to make it appropriate for students living in tropical regions of the continent. Item 3 (scale model of the Earth and the Moon) was rendered in metric units. In the diagram in item 10 (location of the Sun at sunset), East and West were reversed and South was replaced with North. In Item 12 (change in shape of constellation) the Big Dipper was replaced with the Southern Cross and Europe was replaced by South America. In Item 15, distances were replaced by their metric equivalent. Space is provided for respondents to explain their response to all items. This allowed analysis of the written responses to determine the extant alternative conceptions held and to give further insights into the complexity of their thinking.

An additional four items were added that require a drawing-response and which were adapted from Dunlop's Astronomy Survey (2000) developed for primary age students to provide an alternate way of eliciting respondents' understanding of the causes of day and night, the seasons, the phases of the Moon and the orbits of the Earth and Moon about the Sun. In these items, space is also provided for respondents to explain what their diagrams mean.

In this paper, we present analyses of those items that can be directly mapped to the curriculum outcomes of the primary science syllabus and which are again covered in the first year of high school. Thus, of the 25 items in the modified diagnostic instrument, 11 can be considered to assess the knowledge outcomes of the curricula taught both in primary (elementary) school and again in Year 7, the first year of high school. Of the 11 items, two relating to the Moon appear late in the instrument and attracted a very low response-rate (<10%). Consequently, these items have been eliminated from consideration in this paper. Thus, the nine items used in this paper cover the causes of day and night, the apparent movement of the Sun across the sky, the orbits of the Earth and Moon about the Sun, the phases of the Moon, eclipses and the seasons. The remaining 14 items are supposed to be covered by the end of the first three years of high school.

For all of the items, respondents are directed not to guess if they do not know the answer. Rather, they are asked to leave the question blank. The authors were not interested in guesses. We were more interested in what the students thought they knew. That is to say, we attempted to encourage students to respond only to those items for which they thought they had an answer and did not wish to encourage them, as many multiple-choice tests do, to guess at things they had never covered in their science and to overcome the temptation engendered in schools not to leave any question unanswered. In sum, guesses tell us nothing about the alternative conceptions students' hold.

Students' responses were assessed for the correctness of the diagram or the multiple-choice response. The reasons were assessed for the presence or otherwise of alternative conceptions and for their complexity. For the purposes of this paper, only an analysis of the correctness of response and the alternative conceptions evident are presented for the nine items consisting of four drawing and five multiple choice questions.

## Results

This section presents the results for how students responded to the nine items covering the five concepts listed above. A student's drawing or tick-box response was assessed for correctness and the written response was categorised as correct, partly correct, alternative conception, clearly nonsense or a non-response. Attempts were made to match those written responses determined to contain an alternative conception with those reported in the literature (e.g., Lindgren 2003; Ojala 1992). Extensive inter-judge concordance measures were taken to ensure that the alternative conceptions were identified in a reliable manner. The analyses presented here were based on better than 97% inter-judge concordance on the identification of alternative conceptions (Danaia, 2006).

For each of the five concepts, results are organised into two tables. The first presents a breakdown of the classes of responses offered by students in each year level. The second provides the specific alternative conceptions identified in students' written responses.

## *Day and Night*

Table 1 shows the responses of students in Years 7, 8 and 9 to the item related to the causes of day and night. It can be observed that the percentage of students who offered a correct response increases with year level. Disturbingly, only 39.9% of Year 9 students can give a scientifically correct explanation for the causes of day and night.

**Table 1 Student responses to the item related to the causes of day and night**

| Day and Night | Year 7 | Year 8 | Year 9 |
|---|---|---|---|
| Total number of correct responses. | 237 (19.5%) | 159 (31.5%) | 79 (39.9%) |
| Total number of partly correct responses. | 559 (45.9%) | 231 (45.7%) | 63 (31.8%) |
| Total number of responses containing alternative conceptions. | 225 (18.5%) | 73 (14.5%) | 37 (18.7%) |
| Total number of clearly nonsensical responses. | 48 (3.9%) | 8 (1.6%) | 0 (0.0%) |
| Total number of non-responses. | 148 (12.2%) | 34 (6.7%) | 19 (9.6%) |

Table 2 displays an analysis of the alternative conceptions expressed by Year 7, 8 and 9 students related to the causes of day and night. Of those students who offered a response containing an alternative conception, the mean number for Year 7, 8 and 9 respectively was 1.097, 1.068 and 1.000. Table 2 shows that six alternative conceptions were expressed 247 times by students in their first year of secondary school on a concept that is supposed to be covered in the primary school. Of the students who offer an alternative conception, the two most commonly advanced are, “the Earth orbits the Sun daily” and “day and night are caused by the Sun going around the Earth”. Taken together, the frequency of these two responses account for more than two thirds of all of the alternative conceptions expressed by students.

**Table 2 Alternative conceptions related to the causes of day and night**

| Day and Night | Count | | |
|---|---|---|---|
| Alternative Conceptions | Year 7 | Year 8 | Year 9 |
| The Earth orbits the Sun to make night/day. Earth orbits Sun daily. | 32.4% | 30.8% | 45.9% |
| Day and night is caused by the Sun going around the Earth. | 27.9% | 32.1% | 27.0% |
| Day and night is equivalent to the seasons. | 1.2% | 0.0% | 5.4% |
| The Earth orbits the Sun by day and the Moon by night. | 4.9% | 3.8% | 0.0% |
| Moon blocks sunlight at night. Moon orbits the Earth daily. | 7.7% | 11.5% | 5.4% |
| Alternative conceptions related to other phenomena. | 25.9% | 21.8% | 16.2% |
| **Frequency of expressed alternative conceptions** | 247 | 78 | 37 |
| **Mean number of alternative conceptions per student expressing one** | 1.097 | 1.068 | 1.000 |

## *Movement of the Sun*

Students' understanding of the movement of the Sun across the sky is assessed by three items. Since there are 1217 students in Year 7 there are 3651 possible responses. Thus, the percentages presented in Table 3 for Year 7 use the total number of item responses as the divisor. The same approach is used for the divisor for the calculation of percentages in Years 8 and 9.

A high percentage of students in each of the three year groups either did not offer a response or offered a response that contained one or more alternative conceptions. One could hypothesise that students had not been exposed to this concept in primary or early secondary school given that very few from each of the year levels offered either a correct response or even one that was partly correct.

**Table 3 Student responses to the items related to the apparent movement of the Sun across the sky**

| The apparent movement of the Sun across the sky | Year 7 | Year 8 | Year 9 |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Total number of correct responses for any of the items. | 6 (0.2%) | 30 (2.0%) | 22 (3.7%) |
| Total number of partly correct responses for any of the items. | 172 (4.7%) | 105 (6.9%) | 41 (6.9%) |
| Total number of responses containing alternative conceptions. | 1175 (32.2%) | 581 (38.3%) | 213 (35.9%) |
| Total number of clearly nonsensical responses. | 106 (2.9%) | 29 (1.9%) | 12 (2.0%) |
| Total number of non-responses. | 2192 (60.0%) | 770 (50.8%) | 306 (51.5%) |
| **Total possible number of responses.** | 3651 | 1515 | 594 |

Table 4 displays an analysis of the alternative conceptions expressed by Year 7, 8 and 9 students related to the apparent movement of the Sun across the sky. Of those students who expressed one, the mean number of alternative conceptions for Year 7, Year 8 and Year 9 students was 1.015, 1.012 and 1.000 respectively. Table 4 shows that students in their first year of secondary school expressed five alternative conceptions 1193 times for the three items. Of this number, “the Sun always rises in the east and sets in the west” was the most common alternative conception response. The second most common alternative conception is that the Sun is directly overhead at noon every day followed by the presence of the Sun at the zenith on one or two days per year. The latter conception was not the case for the sample of students surveyed since none of them lived within the tropical regions of Australia. A small proportion of alternative conception responses provided by students in all three year levels appear to be derived from sources of information that relate to the Northern Hemisphere, for example, the apparent movement of the Sun where it appears to rise on the “left” and set on the “right”.

**Table 4 Alternative conceptions related to the apparent movement of the Sun across the sky**

| Movement of Sun | Count | | |
|---|---|---|---|
| Alternative Conceptions | Year 7 | Year 8 | Year 9 |
| The Sun always rises in the east and sets in the west. | 38.6% | 40.8% | 39.9% |
| The Sun is directly overhead at noon every day. | 19.8% | 35.2% | 28.2% |
| The Sun is only directly overhead on one or two days per year. | 24.7% | 10.5% | 19.2% |
| Confusion with northern hemisphere. | 13.6% | 11.4% | 12.2% |
| Alternative conceptions related to other phenomena. | 3.4% | 2.0% | 0.5% |

| | | | |
|---|---|---|---|
| **Frequency of expressed alternative conceptions** | 1193 | 588 | 213 |
| **Mean number of alternative conceptions per student expressing one** | 1.015 | 1.012 | 1.000 |

## *Orbits of the Earth and Moon about the Sun*

Table 5 shows the responses of students in Years 7, 8 and 9 to the drawing item on the orbits of the Earth, Moon and Sun. The percentage of correct responses increases from 27.0% in Year 7 through 48.5% in Year 8 to 53.5% in Year 9. Nonetheless, there are many students who either do not know the answer, offer a nonsensical response or possess alternative conceptions in each of the three grade levels.

**Table 5 Student responses to the item related to the orbits of the Earth and Moon about the Sun**

| The orbits of the Earth and Moon about the Sun | Year 7 | Year 8 | Year 9 |
|---|---|---|---|
| Total number of correct responses. | 329 (27.0%) | 245 (48.5%) | 106 (53.5%) |
| Total number of partly correct responses. | 155 (12.7%) | 48 (9.5%) | 15 (7.6%) |
| Total number containing alternative conceptions. | 329 (27.0%) | 111(22.0%) | 30 (15.2%) |
| Total number of clearly nonsensical responses. | 68 (5.6%) | 16 (3.2%) | 5 (2.5%) |
| Total number of non-responses. | 336 (27.6%) | 85 (16.8%) | 42 (21.2%) |

Table 6 displays an analysis of the alternative conceptions expressed by Year 7, 8 and 9 students related to the motion of the Earth, Moon and Sun. Of those students who expressed an alternative conception, the most common one is pre-Copernican indicating that the Moon and/or the Sun orbit the Earth. The second most commonly expressed alternative conception is that the Moon and Earth orbit the Sun together in the same orbital path. Many of the alternative conceptions appear to be variations on a theme of confusion that may be spatially and/or observationally related. The confusion may be attributed to their difficulty of reconciling what they observe (both the Sun and Moon rising in the east and setting in the west) with trying to illustrate the orbits in a diagram.

**Table 6 Alternative conceptions related to the orbits of the Earth and Moon about the Sun**

| Orbit<br>Alternative Conceptions | Count<br>Year 7 | <br>Year 8 | <br>Year 9 |
|---|---|---|---|
| Earth rotates at centre of system and the Sun and/or Moon goes round the Earth. | 57.1% | 51.3% | 43.8% |
| The Moon and the Earth orbit the Sun together in the same orbital path. | 24.3% | 29.4% | 34.4% |
| The Earth orbits the Sun by day and the Moon by night. | 5.7% | 5.0% | 9.4% |
| The Moon orbits the Sun. Earth not mentioned. | 3.8% | 2.5% | 9.4% |
| The Moon goes around the Earth in a single day. | 3.5% | 3.4% | 0.0% |
| The Sun, Moon and Earth go around in the same orbit. | 3.0% | 4.2% | 3.1% |
| Alternative conceptions related to other phenomena. | 2.7% | 4.2% | 0.0% |
| **Frequency of expressed alternative conceptions** | 371 | 119 | 32 |
| **Mean number of alternative conceptions per student expressing one** | 1.128 | 1.072 | 1.067 |

## *Phases of the Moon and Eclipses*

Although four questions of the ADT probed students' understanding of phases of the Moon, their duration and eclipses, two of these items appeared late in the ADT and were not answered by many indicating that perhaps time was a problem. Consequently, these two items have been removed from the analysis. The remaining two items required a drawing response and a multiple-choice response. The drawing item probed students' understanding of the phases of the Moon. The multiple-choice item probed students' understanding of the phase of the Moon at a total solar eclipse.

Table 7 shows that very few students were able to advance a correct response to either question. More than half of the students either chose not to offer any reasons, one that contained an alternative conception or one that did not make sense for the drawing item related to the phases of the Moon. Similarly, a high percentage of students in each of the three year levels could not adequately explain the phase of the Moon at a total solar eclipse.

**Table 7 Student responses to the items related to the phases of the Moon and eclipses**

| **The phases of the Moon** | Year 7 | Year 8 | Year 9 |
|---|---|---|---|
| Total number of correct responses. | 21 (1.7%) | 50 (9.9%) | 20 (10.1%) |
| Total number of partly correct responses. | 363 (29.8%) | 173 (34.3%) | 62 (31.3%) |
| Total number containing alternative conceptions. | 247 (20.3%) | 96 (19.0%) | 37 (18.7%) |
| Total number with clearly nonsensical responses. | 47 (3.9%) | 16 (3.2%) | 3 (1.5%) |
| Total number of non-responses. | 539 (44.3%) | 170 (33.7%) | 76 (38.4%) |
| **Eclipses** | | | |
| Total number of correct responses. | 23 (1.9%) | 37 (7.3%) | 19 (9.6%) |
| Total number of partly correct responses. | 99 (8.1%) | 47 (9.3%) | 25 (12.6%) |
| Total number alternative conceptions. | 559 (45.9%) | 234 (46.3%) | 78 (39.4%) |
| Total number with clearly nonsensical responses. | 13 (1.1%) | 5 (1.0%) | 0 (0.0%) |
| Total number of non-responses. | 523 (43.0%) | 182 (36.0%) | 76 (38.4%) |

Table 8 displays an analysis of the alternative conceptions expressed by Year 7, 8 and 9 students in their responses to the two questions. Of those students who expressed one for the phases of the Moon question, the mean number of alternative conceptions for Year 7, Year 8 and Year 9 students was 1.081, 1.052 and 1.000 respectively. Ten alternative conceptions were expressed 267 times by students in their first year of secondary school for this question. The most common alternative conception related to the phases of the Moon was that, “the phases of the Moon are caused by the shadow of the Earth”. For eclipses, the most common alternative conception was that “An eclipse of the Sun happens at full Moon- only then it is BIG ENOUGH to cover the Sun”. Overall, the data clearly show that a high proportion of responses related to the phases of the Moon and eclipses contain alternative conceptions.

**Table 8 Alternative conceptions related to the phases of the Moon and eclipses**

| **Phases of the Moon** | Count | | |
|---|---|---|---|
| **Alternative Conceptions** | Year 7 | Year 8 | Year 9 |
| Phases of the Moon are caused by the shadow of the Earth. | 27.7% | 29.7% | 51.2% |
| Phases of the Moon are caused by cloud blocking the light reaching the Moon. | 23.6% | 13.9% | 14.0% |
| Phases of the Moon are caused by amounts of sunlight shining on Moon. | 14.6% | 14.9% | 2.3% |
| Phases of the Moon are caused by distance from Earth/Sun | 7.9% | 13.9% | 2.3% |
| Phases of the Moon are caused by the Sun covering Moon. | 7.5% | 6.9% | 14.0% |
| Phases of the Moon are caused by the Sun orbiting Moon. | 3.7% | 3.0% | 7.0% |
| Light reflected from Earth lighting the bit of Moon we see. | 2.2% | 1.0% | 2.3% |
| Different countries see different phases of the Moon on the same day. | 1.5% | 3.0% | 0.0% |
| Moon orbits the Sun. | 6.0% | 5.9% | 0.0% |
| Alternative conceptions related to other phenomena. | 5.2% | 7.9% | 7.0% |
| **Frequency of expressed alternative conceptions** | 267 | 101 | 43 |
| **Mean number of alternative conceptions per student expressing one** | 1.081 | 1.052 | 1.000 |

| **Eclipses** | | | |
|---|---|---|---|
| **Alternative Conceptions** | Year 7 | Year 8 | Year 9 |
| An eclipse of the Sun happens at full Moon- only then it is BIG ENOUGH to cover the Sun. | 85.9% | 83.2% | 78.8% |
| Total eclipses of the Sun can happen at any phase of Moon. | 11.4% | 11.3% | 18.8% |
| Alternative conceptions related to other phenomena. | 2.7% | 5.5% | 2.5% |
| **Frequency of expressed alternative conceptions** | 562 | 238 | 80 |
| **Mean number of alternative conceptions per student expressing one** | 1.005 | 1.017 | 1.026 |

## *Causes of the Seasons*

Table 9 shows the responses of students in Years 7, 8 and 9 to the two items related to the causes of the seasons. A high percentage of students in each of the three year levels could not adequately explain the causes of the seasons. This concept is supposed to be covered in Years 3 and 4 of primary school and again in Year 7.

**Table 9 Student responses to the items related to the causes of the seasons**

| The causes of the seasons | Year 7 | Year 8 | Year 9 |
|---|---|---|---|
| Total number of correct responses for any of the items. | 25 (1.0%) | 48 (4.8%) | 25 (6.3%) |
| Total number of partly correct responses for any of the items. | 226 (9.3%) | 138 (13.7%) | 69 (17.4%) |
| Total number containing alternative conceptions. | 802 (32.9%) | 381 (37.7%) | 122 (30.8%) |
| Total number with clearly nonsensical responses. | 42 (1.7%) | 11 (1.1%) | 5 (1.3%) |
| Total number of non-responses. | 1339 (55.0%) | 432 (42.8%) | 175 (44.2%) |

Table 10 displays an analysis of the alternative conceptions expressed by Year 7, 8 and 9 students. Of those students who expressed one, the mean number of alternative conceptions for Year 7, Year 8 and Year 9 students was 1.121, 1.110 and 1.082 respectively. Six alternative conceptions were expressed 899 times by Year 7 students, 423 times by Year 8 and 132 times by Year 9. The most common alternative conception “the seasons are causes by the Earth’s distance from the Sun” was present in 85.4%, 88.9% and 91.7% of the occurrences in Year 7, Year 8 and Year 9 respectively.

**Table 10 Alternative conceptions related to the causes of the seasons**

| Seasons | Count | | |
|---|---|---|---|
| Alternative Conceptions | Year 7 | Year 8 | Year 9 |
| Seasons are caused by the Earth’s distance from the Sun. | 85.4% | 88.9% | 91.7% |
| The Sun is on one side of the Earth making it hot for 6 months while the other side colder. | 3.8% | 6.6% | 0.8% |
| One side of the Sun is cooler than the other. | 0.8% | 1.2% | 1.5% |
| Clouds in winter block light coming from the Sun weakening it. | 1.6% | 0.0% | 0.0% |

| | | | |
|---|---|---|---|
| The Sun is hot in summer and cool in winter. | 1.6% | 0.0% | 0.8% |
| Alternative conceptions related to other phenomena. | 6.9% | 3.3% | 5.3% |
| **Frequency of expressed alternative conceptions** | 899 | 423 | 132 |
| **Mean number of alternative conceptions per student expressing one** | 1.121 | 1.110 | 1.082 |

# Discussion

Students enter a science classroom with well-developed firmly held beliefs with which they attempt to explain their worlds (Osborne & Freyberg 1985; Tytler 2002; Zirbel 2004). These beliefs are frequently at variance with the views currently accepted by the scientific community and are commonly referred to as alternative conceptions (e.g., Schoon 1995). Many teachers assume that students will acquire the currently accepted scientific conception after they have “taught” it. Research has demonstrated that this simplistic assumption, especially in science education, is not the case (e.g., Taber 2003). Often, students end up with a mixed model comprising their prior beliefs and that which has been presented by the teacher (Chinn & Brewer 1993). The results presented in this research indicate that there are many such mixed models expressed as alternative conceptions about simple astronomical phenomena in students’ responses.

The majority of Year 7 students in this research held alternative conceptions or were unable to provide a scientifically correct explanation about concepts that are supposed to be covered in primary school such as, the causes of day and night, the lunar phases and the seasons. As noted earlier, one would expect fewer alternative conceptions to be evident as students progress through high school. The Year 8 data, however, showed very little reduction in the incidence of alternative conceptions. For the concepts related to the seasons, the apparent movement of the Sun across the sky and eclipses, the Year 8 group displayed the highest percentage of responses containing alternative conceptions. For students in their third year of secondary school science, the number of alternative conceptions was marginally fewer. Nonetheless, a large proportion could not adequately explain the concepts and many chose not to respond at all. From these data, it would seem that the astronomy education to which these students have been exposed has had little impact on their alternative conceptions.

The research literature referred to above asserts that students’ alternative conceptions should be taken into consideration and addressed through the construction of appropriate teaching/learning experiences (Grossman 1990; Shulman 1986). The science education literature details various ways to address these in the classroom (e.g., Osborne & Freyberg 1985; Tytler 2002; Zirbel 2004). Yet, the present study has shown that the science students experience in their first three years of secondary school does not appear to affect the conceptions that are at variance with the currently accepted scientific explanations. If students' conceptions were being taken into account and addressed through the adoption of appropriate instructional methods, then we might expect to see many fewer alternative conceptions and a reduction in their frequency as they progress through high school. The evidence presented here, however, does not support this proposition. Rather, it would seem either that students' conceptions are not being addressed or that appropriate instructional strategies are not being employed. Little appears to have been done to translate the construct of PCK (Shulman 1986) into effective science education practice as far as astronomy is concerned.

A number of possible reasons exist that might explain why the implemented curriculum has been unsuccessful at addressing students' alternative conceptions related to astronomical phenomena and which are clearly articulated in the science education literature (e.g., Dillon et al. 2000; Goodrum, Hackling, & Rennie 2000; Osborne & Collins 2000). These include: the lack of time devoted to science in schools; the overcrowded nature of the science curriculum; the pedagogies adopted; teacher expertise; teachers' own conceptions; and, the content of pre-service teacher education courses. It is clear, however, that these reasons do not exist in isolation one from the other. For example, a lack of time and the overcrowded nature of the science curriculum impact on the pedagogies adopted. Similarly, teacher expertise and the alternative conceptions that they possess also interact with the same two reasons leading to pedagogies that tend to be transmissive rather than constructive.

Australian research (Angus et al. 2004; CRTTE 2003; Goodrum, Hackling, & Rennie 2000) has shown that often science in primary schools is overlooked and not taught at all. It seems that a large percentage of Australian primary school students are exposed to less than 41 minutes of science per week (Angus et al. 2004). It is not surprising, therefore, that students in grade 7 possess so many alternative conceptions given that there is too little time devoted to science for teachers to identify such conceptions and implement learning activities that first destabilise them and subsequently provide pupils with the opportunity to reconceptualise their intellectual models.

Of serious concern is that the prescribed science curriculum in each of the compulsory years of schooling, described as "*a mile wide and an inch deep*" (Schmidt 1999, 92), contains many topics that are supposed to be covered. Given this situation, it is likely that only a minimal amount of time is devoted to specific science topics such as astronomy. It is perhaps not surprising that teachers tend to adopt pedagogies that are not necessarily appropriate for the majority of students to grasp a real understanding of the concepts with which they are presented. Rather transmissive pedagogies are adopted that are designed to allow the content to be covered at a faster pace. Consequently, teachers have little time to pre-assess students and determine their alternative conceptions before commencing a topic in science.

Perhaps teachers do not possess adequate pedagogical content knowledge to teach such concepts. That is to say, they fail to take into consideration and build on students' conceptions both before, and during, teaching and learning experiences, they have limited content knowledge and they are not equipped with the appropriate instructional strategies required to teach the astronomical concepts. It has been reported that in secondary schools, many teachers are teaching outside their area of expertise (Harris, Jensz, & Baldwin 2005). This is in part due to the shortage of specialist science teachers with physics or astronomy qualifications within secondary schools (CRTTE 2003; Harris, Jensz, & Baldwin 2005). In Australia, all science teachers are required to teach outside their area of expertise at the junior secondary level. It is clearly evident that in the case of astronomy education there is a price to pay as has been illustrated in this paper. One could hypothesise that similar situations exist when physics teachers are required to teach biology or botany. In these cases, it is likely that teachers have limited content knowledge and may possess alternative conceptions expressing these in their teaching of such concepts.

Many studies have shown (e.g., Trundle, Atwood, & Christopher 2006) that both pre-service and in-service teachers hold alternative conceptions for a diverse range of scientific concepts and are likely to communicate these to their students in the teaching/learning context. Consequently, teachers need to take into consideration not only students' conceptions but also their own and consider them in relation to the currently accepted scientific beliefs. In all probability, the PCK necessary to teach such concepts has not been given due recognition in Australian teacher education courses. Is it therefore any wonder that students' continue to possess alternative astronomical conceptions when teachers may not themselves possess the expertise, have alternative conceptions and/or have had limited exposure to the importance of PCK in their training.

If these problems are to be overcome, it necessitates that the breadth of the curriculum be reduced. This will allow teachers more time to cover fewer topics in depth and employ more appropriate pedagogies allowing students to redress their alternative conceptions. It will also likely have additional benefits where teachers can deal with their own alternative conceptions through addressing their lack of content knowledge. Pre-service teacher education courses need to equip pre-service teachers with the necessary skills to identify and address not only their future students' alternative conceptions but also their own (McKinnon & Danaia 2005; McKinnon, Danaia, & Parkes 2007). Furthermore, ongoing professional development for teachers of science is necessary to support them in developing more extensive content specific PCK.

The issues alluded to above prompt a number of questions: Do primary and secondary teachers of science possess adequate PCK necessary to teach the wide array of topics in the science curriculum that are supposed to be covered? Are the science subjects within pre-service teacher education courses providing prospective teachers with the necessary PCK essential to teach the different sciences? What happens when students' alternative astronomical conceptions are taken into consideration before implementing an astronomy topic in science? If astronomy education is taken as an indicator of the health of science education, then it is likely that similar problems exist in other physical-science subjects. Is it then any wonder why fewer students are pursuing further study in the physical sciences?

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