Framing, Assessing and Developing Children's Understanding of Time

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An understanding of time which goes beyond the reading of clocks and calendars is crucial to full participation in society. This paper reports on classroom experiences and pedagogies that assisted Year 3/4 children's development when learning about time, drawing upon a Framework for the Learning and Teaching of Time, interview data, an eight-lesson intervention and student improved performance on the interview following the intervention.

Introduction and Theoretical Framework

Time is complex, but it plays a crucial role in our full participation in society. An understanding of divisions of time and temporal patterns allows adults to anticipate future events (Friedman, 1991, 2000; Hudson & Mayhew, 2011) and to have memories of times past. Fraisse (1984) considered time as an intricate subject, being associated with world time and personal time. Friedman (2011) described time as "many things: recurrent sequences of events, natural and conventional time patterns, invariant causal sequences, logical relations between succession and duration, the past-present-future distinction and many others" (p. 398).

The learning and teaching of time is listed in the *Australian Curriculum: Mathematics* under Measurement with the focus on students learning to operate with clocks and calendars (Australian Curriculum Assessment and Reporting Authority (ACARA), 2016). Personal classroom experience, other teachers' anecdotes and past NAPLAN test results accord with some research literature (e.g., Kamii & Long, 2003) in convincing us that for some children the concept of time is complex and complicated. The teaching of time should include a broad range of experiences (Casasanto, Fotakopoulou, & Boroditsky, 2010; Kamii & Long, 2003; Piaget, 1969) and include aspects of time such as duration and succession (Fraisse, 1984; Vakali, 1991) and psychological time (Friedman, 1978; Vakali, 1991). Dickson, Brown and Gibson (1984) emphasised the distinction between telling the time and a concept of time as children may be trained to read the dials on a timepiece but have difficulty in understanding a concept of time. Other studies consider an understanding of time develops gradually from infancy to adolescence (Friedman, 2011; Piaget, 1969; Trosborg, 1982). While scholars have contributed to our understanding of concepts of time and its development, it would seem there is a paucity of research relative to other curriculum areas.

The perceived inadequacy of both the curriculum and the dearth of research literature led to the development of a more comprehensive Framework for the Learning and Teaching of Time ("the Framework", see Figure 1) that encompassed major underpinning

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components of time, the first version of which was reported in Thomas, Clarke, McDonough and Clarkson (2016).

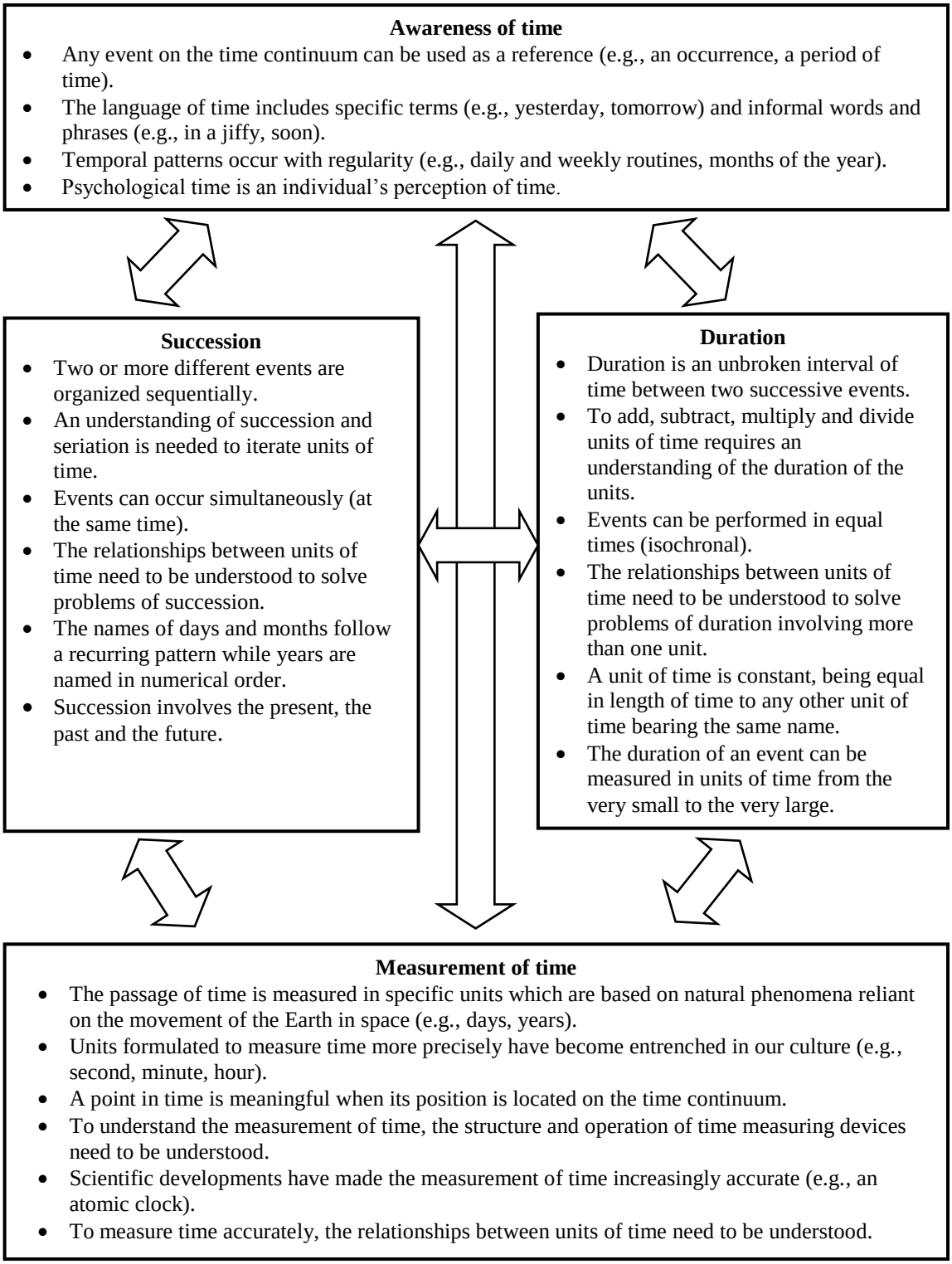

Figure 1. A Framework for the learning and teaching of time.

It was argued that for students to understand, interpret and to be fully equipped to use time effectively, they need to have an understanding of these four components: an Awareness of time, an understanding of Succession of time and Duration of time, and be able to Measure time. The key ideas listed as dot points under each component further explain the Framework and add to its value and importance for teachers and researchers alike.

After analysing the data from an eight lesson intervention focussing on time, the Framework was reviewed with several refinements being made to improve its clarity. The final version of the Framework is presented in Figure 1. Apart from presenting the final version of the Framework, this paper also reports on an eight lesson teaching intervention and pre and post students' results from a one-to-one interview tool outlined previously (Thomas, McDonough, Clarkson, & Clarke, 2016).

Methodology

The one-to-one interview was selected as an assessment tool as it was considered to be an informative and reliable tool. Clements and Ellerton (1995) had raised questions about the reliability of pencil and paper tests to assess mathematical understanding, whereas by talking to students in a one-to-one interview, teachers are able to develop a deeper understanding of the students' thought processes (Webb, 1992), strategies and cognitive processes (Ginsberg, 2009). When interviewing their students, teachers are able to diagnose misconceptions and assess a student's ability to express mathematical knowledge verbally (Huinker, 1993), particularly during the early years of schooling when reading and writing skills may be limited (Clarke, 2001).

The Framework was the basis for the development of the one-to-one task based interview to assess a group of Year 3 and 4 students on their understanding of time (Thomas, McDonough, et al., 2016). Twenty-seven students from a class of 30 (5 girls and 9 boys from Year 3 and 6 girls and 7 boys from Year 4) were interviewed on two occasions; the first interview was prior to the eight lessons, with the second interview three weeks after the intervention. The interview proved to be a comprehensive assessment tool as it was formulated around three of the four major components of the Framework (Succession, Duration and Measurement). Awareness of time was deemed to be incorporated into each item and hence it too was assessed, though not reported specifically.

Each item had a range of anticipated responses. Responses to each of the 69 items which were assessed as demonstrating a full understanding gained two points, a partial understanding gained one point, and if the student demonstrated no understanding at all, they did not gain any points. This marking regime followed that of Clements and Ellerton (1995). To analyse each student's understanding of each component of the Framework, their points for each item listed under that component were tallied and a score given. A total score for all items was also calculated to give an overall summary for each student and to allow for comparisons to be made between students. Addressing each of the key ideas in the interview proved to be an effective way to assess each student's understanding of each component.

It was decided to make the focus of the intervention lessons the mathematics underpinning those interview items for which the total score from the class was less than 75% of the maximum possible score (a raw score of 40 or less from a maximum possible score of 54) on the pre-test. Although 75% was a somewhat arbitrary figure, it indicated those key ideas for which improvement was desirable and hopefully achievable. A sample of items for which performance indicated the need for attention in the eight lessons is

shown in Table 1 alongside the score for the item and the components assessed: S (Succession); D (Duration); and M (Measurement).

Investigation of the individual student scores on the pre-test showed that fewer than half the students scored more than 75% in any of the components. For the Succession items there were 11 students who gained more than 75%, for the Duration items there were 3 students, and for Measurement 11 students scored over 75%. Although the highest score achieved by a student was 90%, the results demonstrated the need for the eight lesson intervention, as it was anticipated that all students would benefit in some way.

Table 1
A Sample of Items for Which Performance Indicated Needed Attention in the Eight Lessons

Interview item	Score and Component	
What can you tell me about the rotation and revolution of the Earth?	6	SDM
If you had a calculator, how would you work out your age in days?	10	DM
Tell me how we use clocks to measure time.	11	DM
Today is Wednesday. When will Wednesday finish?	19	SD
What units to measure time do you know?	27	M
What was the date exactly one month ago?	29	SM
Write this digital time as seen on an analogue clock. ¼ to 6.	30	M
How long does it take for the hour hand to move from the 8 to the 9?	32	DM
I have been given enough eggs for exactly one week (one per day). If I ate the first egg on Wednesday, which day would I eat the last egg?	32	S
How many minutes does it take for the minute hand to move from 4 to 5?	35	DM
What will the date be two years from now?	36	SM
What year were you in Prep?	40	SM

The eight lesson intervention focussed on student activities related to the measurement of time such as the rotation and revolution of the Earth, the observation of seconds and minutes on working clocks, and the measurement of hours from any given minute on the clock face. As a stimulus to their thinking, each lesson began with a text that related to the focus of the lesson. The texts, which included both fiction and non-fiction, were read to and discussed with the children. Data collected from the lessons included audio-recording of the children completing the tasks, anecdotal notes from classroom observations, classroom artefacts such as children's written and drawn task recordings, and letters and self-reflections written by the children about their learning. Three weeks after the intervention, the children were reassessed using the same one-to-one task based interview.

Results

The maximum number of possible points gained by responding to all items of the interview with full understanding was 138 (Succession 56, Duration 62, and Measurement 98). The maximum scores for components do not sum to 138 as a number of items were linked to more than one component. (Note the double arrows in Figure 1 which suggest overlap between the components.) The results from the pre-intervention interview show that from a possible maximum score of 138, the students' scores ranged from 48 to 124,

with a mean score of 93.4, and a median score of 96 (see Table 2). All the students showed an improvement in their scores for the post-intervention interview, with scores ranging from 63 to 133, with a mean score of 108.0 and a median score of 112. The minimum score increased from the pre-intervention interview to the post-intervention interview by 15 points and the maximum score increased by 9 points.

Table 2
A Comparison of Scores: Pre-Intervention and Post-Intervention Interview

	Pre-intervention Interview	Post-Intervention Interview
Mean	93.4	108
Media	96	112
Minimum	48	63
Maximum	124	133
Maximum Score possible	138	138

Although all students gained a higher *total* score for the second interview, not all of the students' scores on *individual* interview items increased. Of the 1863 responses to the individual items, 432 scores (23%) increased, 1,263 scores (68%) remained the same, and 168 scores (9%) decreased. A more detailed analysis for the increase and decrease in scores by item can be seen in the crosstabulation in Table 3.

Table 3
Student Responses from the Pre-and Post- Intervention Interviews

		Post-intervention interview			
		0	**1**	**2**	**Total**
Pre-intervention Interview	**0**	152	96	184	**432**
	1	42	146	152	**340**
	2	52	74	965	**1091**
	Total	**246**	**316**	**1301**	**1863**

Clearly by far the majority of responses (52%) are in the cell 2 > 2 implying that for many items, students scored maximum points in the first interview and did so again when interviewed the second time. In other words, these students had reached a ceiling in this scoring regime before any intervention and for these items. It was expected for many reasons that some students might fall from an initial 2 back to zero, and this did happen, but for relatively few responses (3%). More encouraging, ten per cent of responses moved from zero to 2.

A further useful set of analyses is the changes that occurred for each of the three components of the Framework targeted by this assessment tool. The relative descriptive statistics for Succession, Duration and Measurement are shown in Table 4.

Table 4
Descriptive Statistics for Succession, Duration and Measurement

	Succession		**Duration**		**Measurement**	
	Sept 2015	Nov 2015	Sept 2015	Nov 2015	Sept 2015	Nov 2015
Mean	38.7	43.7	36.1	44.8	65.7	76.7
Median	40	44	35	47	66	78
SD	6.8	6.3	9.4	8.0	16.0	13.0
Minimum	16	23	13	26	29	38
Maximum	50	54	54	59	88	96

In summary, the results in Table 4 suggest that this group of students not only improved their overall performance on interview items linked to the Framework, but there was improvement in their performance on each of three components: Duration, Succession and Measurement. For some insight as to why this improvement did occur it is instructive to review key elements of the intervention pedagogy.

Discussion

The significant improvement in children's understanding can reasonably be attributed to the eight lessons and in this section we outline the key pedagogies that we believe led to the students' improved scores from the first to the second interview.

1. Literature. Each lesson began with the reading of a book to the children. The text was directly related to the focus of the lesson and was selected to promote interest in the topic and engage the children in discussion. For example, *Clocks and more clocks* (Hutchins, 1970) promoted discussion on duration. Reading and discussing children's books which relate to the mathematical focus of the lesson has been found to enhance the students' learning of mathematics (Elia, van den Heuvel-Panhuizen, & Georgiou, 2010; van den Heuvel-Panhuizen, van den Boogaard, & Doig, 2009).

2. Physical involvement. One of the most notable lessons involving the movement of the children was a lesson relating to the rotation and revolution of the Earth in space. As the children had limited knowledge of the Earth's movements, the teacher-researcher introduced them to rotation and revolution by firstly reading a story, and secondly, by having the children act out the movement and position of the Sun and the Earth whilst giving a narrative of their actions. Informal discussions during the days on the intervention, and an increase in scores for the interview item about rotation, led us to the conclusion that this lesson was one of the most memorable because of the physical involvement.

3. Equipment. The selection of equipment for each lesson played an important role in engaging the students in each activity. The most useful pieces of equipment were real clocks. In order for the children to be able to measure the passing of time, it was essential for them to use working clocks to observe the second and minute hands moving. The use of real clocks meant that the children could 'see' the duration of a second or a minute and appreciate that a minute is measured on the clock by the space that the hand had moved

through with the minute lines showing the beginning or end of the duration. Seeing the movement of the hands as the clock ticked assisted the children to count elapsed minutes and seconds and to understand how a clock is read. Other important pieces of equipment were sand timers, which were checked for accuracy with a clock, large balls used as the Earth and the Sun, and items such as laminated numbers and walking sticks, to build a clock on the floor.

4. Correct terminology. The use of the correct terminology was instrumental in assisting the children to understand the focus of each lesson. The children who were accustomed to the terms 'big hand' and 'small hand' were intrigued to find that these hands could just as easily be named the 'hour hand' and the 'minute hand' thereby reducing any confusion. Terms such as duration and succession were used frequently after being introduced to the classroom.

5. Group work, discussion and self-reflection. The classroom teacher's mathematics groups comprised students with similar levels of understanding, based on her assessment. The activities undertaken during the intervention relied however on mixed ability groups working together and discussing their findings. At the conclusion of each lesson, children were encouraged to share their learning with the remainder of the class to reinforce their learning following which, all the children were required to write a self-reflection to consolidate their individual learning experiences. To assist their reflections, the children were given a different strategy each lesson. For example, a 3, 2, 1 reflection required children to list three things remembered from the lesson, to give two examples of something they had learned, and to write one question regarding something which was confusing to them. The self-reflections encouraged the students to consider the purpose of each lesson. At the commencement of the following lesson, the students were asked to recall what they had learned during the previous lesson.

6. Time to complete a variety of activities. Timetabling eight lessons for the intervention allowed many different activities to be experienced by the children. Lessons were planned to be sequential so that ideas from one lesson could be developed further in the next lesson. Past lessons were reviewed at the commencement of each new lesson, so that questions could be asked and ideas shared.

Summary

The 69 item one-to-one interview was shown to be very effective in identifying assumed strengths and weaknesses in the children's understanding of time. Prior to the intervention, the children did not appear to understand the notion of time being measured and that units such as second, minute and hour were used to measure durations of time. Introducing the children to the rotation of the Earth gave many of the children an understanding of a 24 hour day which includes periods of light and dark. Observing the revolution of the Earth around the Sun helped the children to understand why the calendar year has 365 days and why we intercalate a day every four years to make a Leap Year. By observing the second and minute hands of a working clock as they moved across the spaces between the minute marks, the children could 'see' the clock measuring the duration of a second and a minute. Giving the students real clocks, a variety of activities, interesting books and time to reflect on and discuss their learning were all found to be beneficial to the children's improved understanding of time.

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Practical Implications

The Australian Curriculum: Mathematics lists the learning and teaching of time under Measurement with the focus on students learning to use the tools of time measurement: clocks and calendars (Australian Curriculum Assessment and Reporting Authority (ACARA), 2016). The outcomes to be achieved by the end of Level 3 include knowing the months and the seasons, a knowledge of the calendar, and reading a clock to the minute. But the concept of time has been found to be complex and challenging for many children and much more than just its measurement (Casasanto et al., 2010; Dickson et al., 1984; Kamii & Long, 2003; Piaget, 1969). Despite some research on the development of our understanding of concepts of time (Friedman, 1991, 2000; Friedman & Lyon, 2005; Hudson & Mayhew, 2011), there seems to be a dearth of research into the learning and teaching of time. In this study we have identified major components of time and incorporated them into a Framework for Learning and Teaching Time, developed a one-to-one task based interview to assess student understanding, and undertaken an eight lesson intervention on time. The practical implications for each are detailed below.

The Framework for the Learning and Teaching of Time. The Framework incorporates four major components of time: Awareness of time, Succession, Duration and Measurement of time. Rather than being a linear model, the Framework demonstrates how notions of time are not learnt in sequence, but over an extended period in interconnected ways, ensuring a deep understanding. Awareness of time includes knowing about a point in time, the language of time, temporal patterns and psychological time. The literature indicates that an Awareness of time seems to be the natural starting point before moving to untangle the deeper notions of the Framework (Ames, 1946; Friedman, 1977, 1990). Succession is the sequential ordering of time (Fraisse, 1984). Duration is the passage of time, with each duration requiring a starting and a finishing time (Fraisse, 1984). The Measurement of time is crucial to the understanding of time, requiring a knowledge of specific units of time and time measuring tools. The Framework has been designed as an important tool to inform both teachers and researchers, and to guide curriculum writers and teachers in the planning and implementation of lessons on the concept of time. By emphasizing the interconnectedness of the components, we try to counteract the notions of teaching each independently and serially.

The one-to-one task based interview. The interview has been designed to assess children in the middle primary school years on three of the four major components of the Framework: Succession, Duration and Measurement of time. Children in the middle years of primary school were assumed to have an Awareness of time, and as such, it was not assessed separately but deemed to be incorporated into each item. An individual child's responses to the 69 items in the interview are calculated to inform the teacher of his/her apparent strengths and weaknesses in each of the four major components of time. The interview has been designed to be repeated over time as not all children are expected to demonstrate full understanding of each item. The interview proved to be easy to use but offered informative insights.

Pedagogies implemented during the eight lesson intervention. Given that all students improved in their understanding following the intervention lessons, as measured by the assessment interview, it is important to describe the underlying pedagogies of the lessons. Based on the experience of teaching the lessons, we would encourage the use of picture books and actual working clocks in any lesson dealing with time. Using correct

terminology such as minute hand and hour hand aids in reducing the confusion some children experience when identifying the hands of the clock. Language such as rotation, revolution, duration and succession were readily learnt and used by students. Children need a variety of experiences when learning about time, and active involvement was important with students drawing, writing and discussing their ideas. Activities related to time need to be timetabled regularly and over a lengthy period to promote learning, as time is not just important in mathematics. We would recommend children be given opportunities to draw, write, discuss and share their learning throughout the lesson, particularly at the end.

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