

# Understanding Time: A Research Based Framework

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Time is crucial in our society. However, it would appear that there is limited research on the learning and teaching of time. Curricula appear to place an undue emphasis on the reading of time measuring tools. We argue that key ideas of succession, duration, and measurement should be central to learning about time. Drawing upon available research, this theoretical study developed a framework of core ideas that underpin a full understanding of time, can inform curricula, and drive future research.

Time has always been a part of our existence. Although time cannot be seen, we experience a sense of time and we are time conscious. Early civilisations began to measure the daylight hours and in the Middle Ages mechanical clocks were developed to assist with calls to prayer and denote working hours (Barnett, 1998; Dohrn-van Rossum, 1996). Over the centuries, more sophisticated methods of measuring time have been developed. While time is still measured according to natural phenomena, the day, the lunar month and the year; other divisions, or units of time, have been introduced to measure time segments from the very small, nanoseconds, milliseconds and seconds, to the immensely large, decades, centuries, millennia, eons and eras (Barnett, 1998).

Time is measured constantly. Like other forms of measurement, time can be separated into units that are iterated to form longer periods. Despite advances by scientists such as Einstein, whose work on simultaneity brought him to the theory of relativity where time is no longer considered absolute, and Bohr, whose study of the nucleus of an atom led to the atomic clock (Barnett, 1998; Dohrn-van Rossum, 1996; Hawking, 1988), the units of the day, week and month are still important features of daily lives (Moore-Ede, Sulzman, & Fuller, 1982). Calendars are used to measure the days and months in a year; the time the Earth takes to revolve around the Sun. Clocks are used to measure smaller units of time, the hours and minutes in a day; the time the Earth takes to rotate once on its axis.

As the Earth revolves around the Sun our Earth experiences seasons, and as the Earth rotates, we experience night and day. A knowledge and understanding of Earth's position in this cyclic process allows us to plan and prepare for events such as the coming of winter and the onset of night. For early civilisations, a knowledge of seasons and daylight hours was sufficient, but the need to measure and record time more precisely is a feature of our daily lives. Significant events and sporting achievements are recorded. Newspapers, documents, diaries and journals are distinguished from one another by the date of publication. Public transport is run according to timetables. Meetings, appointments and contacts are arranged according to calendars and clocks. The measurement of time puts the present into the continuum of past, present and future. An understanding of divisions of time and temporal patterns allows adults to anticipate future events (Friedman, 2000; Hudson & Mayhew, 2011) and to have memories of times past (Friedman, 1991; Hudson & Mayhew, 2011).

Time is, therefore, an important topic in the mathematics curriculum. Students need to develop a deep understanding of the concept of time if they are to read and interpret the tools we use to measure time; the clock and the calendar. In this theoretical paper we explore the issue of deep conceptual understandings of time, something we show has been paid little attention in the research literature, and by presenting a framework of such ideas suggest how they are related and could form a more insightful basis for teaching and curriculum development.

## The Learning and Teaching of Time

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). Time, like length, volume, area and mass, is measured, but unlike these attributes, time does not have physical attributes that children can experience through sight and touch when they are measuring. As with other attributes, the teaching of time to children is complex, as developing a knowledge of time is linked to space, distance and speed (Casasanto, Fotakopoulou, & Boroditsky, 2010; Piaget, 1969). Hence teaching time should be more than teaching them to read clocks (Kamii & Long, 2003).

When children are learning about time, many aspects of time need to be considered, such as duration and succession (Fraisse, 1984; Piaget, 1969; Vakali, 1991) as well as psychological time (Friedman, 1978; Vakali, 1991). Friedman (1978) stated that time seemed “to be a physiological, perceptual, cognitive, and social, as well as a natural phenomenon” (p. 268). While the reading of clock times is important for children, clock knowledge requires not only an ability to read the time from the clock face and to operate on these times to promote relationships, but also requires an understanding of where a time occurs within the day and what activities might be happening (Friedman & Laycock, 1989).

Although time as a concept is intangible for children, it is present in their lives as they learn to be at school on time or are permitted to stay up later than their usual bedtime (Buys & Veltman, 2005). Over our lifetimes, we experience recurring temporal patterns (Friedman, 1990), from the daily rising and setting of the sun to yearly cycles of seasons, birthdays and special events. However crucially, there is a distinction between telling the time and the concept of time. Children may be trained to read the dials on a timepiece but still have difficulty in understanding the concept of time (Dickson, Brown, & Gibson, 1984). This deeper conceptual understanding of time is clearly part of the developmental process which occurs gradually from infancy to adolescence (Friedman, 2011; Piaget, 1969; Trosborg, 1982), but the school curriculum has its role to play as well.

While there have been some studies into what children understand about time and the language of time (Ames, 1946; Friedman, 1978, 2000; Friedman & Laycock, 1989), there have been few studies dealing with how children learn about time, how teachers can teach most effectively or how many hours should be allocated to this topic. As an illustration of this, of the 1,630 plus research papers presented at the annual conferences of the International Group for the Psychology of Mathematics Education (IGPME), the major international conference on research into mathematics education, in the last ten years, only *one* paper mentioned the topic of time (Doig, Williams, Wo, & Pampaka, 2006). Doig et al. (2006) collected responses to a test on measurement from 14,000 students, and in their paper, reported on one item in the test on the attribute of time.

Surprisingly perhaps, a major research project, the Early Numeracy Research Project (Clarke et al., 2002), although acknowledging the importance of duration and giving some insights into children's developing understandings, had little more to say about time in general and the learning and teaching of it. Later, a small study by Clarke (personal communication) surveyed 76 teachers from Victorian Catholic primary schools. The teachers taught classes ranging from Prep (first year of school) to Year 6. As part of the study, teachers were asked to estimate the hours spent each year teaching time. The results show that more hours were estimated to be spent teaching time informally (ranging from 2 to 100 hours with a median of 20 hours) than formally (ranging from 3 to 30 hours with a median of 10 hours). The range indicates the lack of a consistent emphasis across schooling. Clearly more research is needed in this area.

So, although in the literature there is limited reporting of research targeting the actual learning and teaching of time, there is more to be found in the discussion of key underlying ideas of which our deeper understanding of time rests. Fraisse (1984), Friedman (1977, 1991, 2000) and Vakali (Vakali, 1991) have emphasised the importance of *succession* and *duration*, two such key ideas. Succession is the sequential ordering of two or more different events, whereas duration is the interval of time between the two events. To some degree these two notions are also interdependent. An understanding of succession is needed to understand duration.

The notion of time applies to two different concepts ... the concept of succession, which corresponds to the fact that two or more events can be perceived as different and organized sequentially ... is based on our experience of the continuous changing through which the present becomes the past; [and] the concept of duration which applies to the interval between two successive events" (Fraisse, 1984, p. 2).

Duration, as the interval between two separate events, cannot exist without the idea of succession (Fraisse, 1984). Interestingly, Trosborg (1982) conceived time as being subdivided into punctual and durative aspects, the punctual aspect being a point in time while the durative aspect is continual. The importance of succession in learning about time becomes evident when iterating periods, or units, of time. Duration is important when assessing the length of periods, or units, of time such as the minute or the hour. An understanding of duration is required to know that one hour of time equals another hour of time in a different part of the day; and that a minute is always the same length whenever it occurs.

Although children perceive succession and duration from an early age, they are unable to combine the two ideas until sometime later (Fraisse, 1984; Piaget, 1969). Piaget (1969) claimed that succession and duration develop at the same time, but this was disputed by Levin (1978) who found that duration was a more difficult concept for children and consequently developed later. Judgements of duration by young children are influenced by cues such as distance and speed (Levin, 1979; Levin et al., 1978; Trosborg, 1982). Many children under the age of seven confuse space and time believing that a body moving for a longer duration must go further (Casasanto et al., 2010; Levin, 1977; Piaget, 1969) and a body moving faster will take a longer time to cover a given distance than a slower body (Lovell & Slater, 1960; Piaget, 1969). Further studies by Siegler and Richards (1979) confirmed the idea that children understand the concept of speed well before the concept of time. Additional confusions for children occur when the same language is used for both space and time, such as long and short, and distances are measured in a few minutes, as in 'the shop is just a few minutes down this road' (Casasanto et al., 2010).

Given the limited research undertaken into how children come to understand these deeper ideas, it seems that curriculum developers have taken the option of dealing with the surface issues of how one learns measurement techniques. This is not to say that our society, knowing how to measure time and reading the appropriate instruments for such is not important knowledge, but it does not deal with the relational ideas which underpin such measurement.

An examination of the curricula of Australia (Australian Curriculum Assessment and Reporting Authority (ACARA), 2014), England (Department for Education, 2014), the United States of America (Common Core State Standards Initiative, 2014) and Singapore (Ministry of Education Singapore, 2014) showed a heavy emphasis on the reading of time, but little on the understanding of succession and duration. These core ideas should feature in our curriculum documents and subsequently, what is being taught if relational understanding is to occur. For example, items on time listed in the Australian curriculum include the days of the week, the months and the seasons; telling the time to half hour, quarter hour, five minutes and one minute; and the language of *past* and *to*, measuring time in hours, minutes and seconds. It is true that there are some topics in the curriculum that do relate to duration and include a formal comparison and ordering of the duration of events, as well as describing duration using months, weeks, days and hours, but no actual mention is made of the concepts of duration and succession.

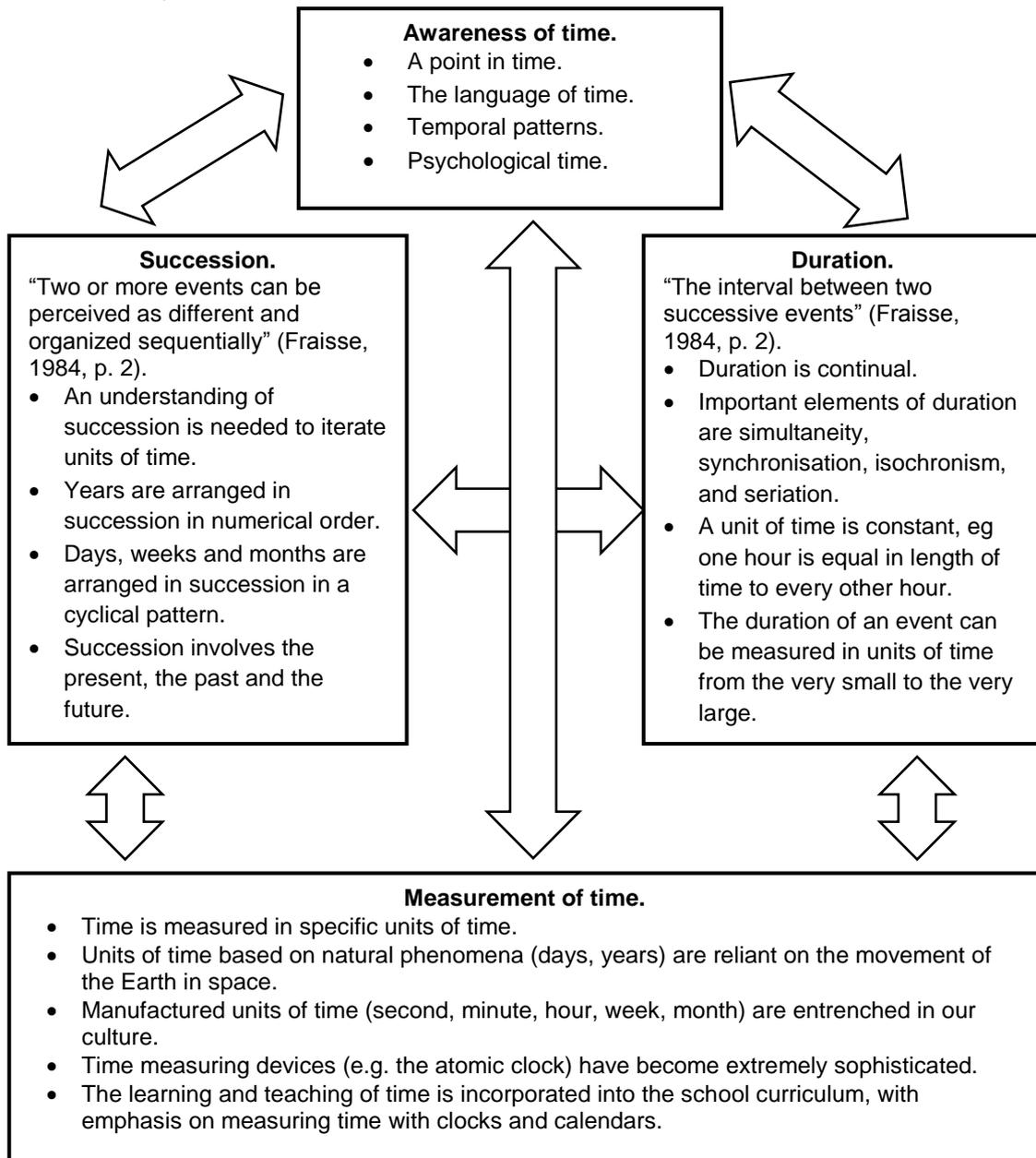
In Australia, a major measure of how well students are dealing with the curriculum is through the annual NAPLAN tests in years 3, 5, 7 and 9 (Australian Curriculum Assessment and Reporting Authority (ACARA), 2011). An inspection of the tests since NAPLAN's inception suggested that there were few questions on time. Further, the results from the tests indicated a lack of understanding by students in all the year levels assessed. By way of example, the percentages of correct responses in 2013 are shown in Table 1. Consistently low percentages of correct responses over the years raised concerns for the first author in this study about the students' understanding of time concepts.

Table 1  
*Percentage of Correct Responses to Time Questions from the 2013 NAPLAN Test*

2013 questions	Year 3	Year 5	Year 7
Reads an analogue clock to the half hour.	71		
Uses a calendar to determine the date of an event.	33	50	
Calculates an elapsed time in hours and minutes.		60	
Calculates an elapsed time from pm to am in hours and minutes.			49
Calculates time from a given speed and a distance.			59

## A Proposed Framework

Given that there seems to be a dearth of research on the actual deep learning and teaching of time, it seemed appropriate to draw together key ideas underpinning the concept of time and develop a framework that could lay a firm foundation for the learning and teaching of time. Using the literature, a framework which juxtaposed key underlying ideas of the concept of time was developed (see Fig. 1.) We believe this to be far more comprehensive than what is in the curricula that have been examined. *Succession* and *Duration* discussed above, were two notions that are lynchpins of the framework. However, before these notions come into play for children there is what we have termed an *Awareness of time*. The fourth component in the framework is the very important *Measurement of time*.



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

The first box, *Awareness of time*, seems to be the vital starting point to understanding the concept of time. While some of these aspects of time are in the Australian curriculum (ACARA, 2014), teachers cannot assume that students commencing school have a thorough awareness of the passing of time, so it is important that each dot point is dealt with in the classroom. *A point in time* refers to a specific instant, occurrence, or period of time that can be used as a reference point (e.g. special events, memorable days and moments). *The language of time* includes not only specific terms (e.g. yesterday, tomorrow, last week), but also more informal words and phrases (e.g. wait a minute, in a jiffy). *Temporal patterns* refers to the timelines of daily events, weekly routines, and cycles of time such as school days, months and seasons. *Psychological time* is our perception of time. In our thinking and in the literature (Ames, 1946; Friedman, 1977, 1990) an *Awareness of time* seems to be the natural starting point before moving to untangle the deeper notions of the framework.

The boxes on either side of the diagram indicate the need for students to understand the concepts of *Succession* and *Duration*. Without an understanding of *Succession* and *Duration*, we suggest that the reading of clocks and calendars may be meaningless, as the students fail to put the time into context. *Succession* is the sequential ordering of time (Fraisie, 1984). Years are named in numerical order, days and months follow the same order on a calendar, and clocks measure the hours in a numerical sequence over a 12 or 24 hour period. *Duration* is the passage of time, with each duration requiring a starting and a finishing time (Fraisie, 1984). Duration can be measured simply using hand claps and sandglasses, or more precisely with advanced technology such as atomic clocks. To read time measuring tools and to understand what the tool is telling us, students need to understand that each period of time (e.g. minute, hour, week or year) follows another (succession). It is also important to know that each time period (e.g. second, minute and hour) is always the same length (duration). Elements of duration include simultaneity (events occurring at the same time, coincidence), synchronisation (keeping time together, agreeing in time), isochronism (of equal time, performed in equal times), and seriation (arranged in a series, in order).

The *Measurement of time* is crucial to the understanding of time. Measuring time requires a knowledge of specific units of time and time measuring tools. The learning and teaching of units and tools for measuring time is incorporated into the school curriculum although, as discussed earlier in this paper, it appears that the focus is on reading the time tools, such as clocks and calendars, to ascertain a point in time. Knowing that time is measured underlies a deeper understanding of the concept. When we read the time for example as five minutes past six, or 6:05, we are recording the measurement of time from twelve o'clock. The clock informs us that six hours and five minutes have elapsed since twelve o'clock (duration), and that we have moved into the seventh hour (succession).

The arrows are positioned carefully in the framework to show the connections between each component of the framework. We have used arrows to show that each component is linked to each other component. However, we have used double-headed arrows deliberately since we understand there is often a dynamic set up between the components of the framework. This is not a simple linear model. Not all notions of succession are learnt at one point in time but different ideas embedded in succession are learnt over a period of time and as this occurs so too does a deeper understanding of duration occur. Interestingly, we think that while this is occurring, then a child's awareness of time and its significance to their own lives will also expand and deepen. We also assert that while this ongoing and complex process is occurring students will gradually deepen their understanding of why

measuring of time is undertaken in particular ways depending on the context that is presented.

Having established a framework for the notion of time, we have already used it in the next stage of the study to investigate what aspects of time were understood and misunderstood by students, respectively. Drawing on a variety of resources, including literature and teacher anecdotal evidence, a questionnaire was developed with 74 questions to be asked of children in Years 3 and 4 in a one-to-one, task-based interview. The interview questions were refined and revised through a pilot program at a trial school. The final interview was conducted twice with 27 Year 3 and 4 students at a regional Victorian government school, prior to and one month after participating in an eight-lesson unit of work on time, written by the first author. In a further paper (Thomas et al., forthcoming), a summary of results from the interviews, and important insights about students' understanding of time will be presented.

## Conclusion

This theoretical study has shown that the learning of time concepts, while very important to participation in society, is an under-researched topic, and one that can be challenging for many students. Teachers need further guidance on the teaching of time in order to help their students to learn. The framework proposed in this paper has placed into a simple framework core notions that underpin the deeper understanding of time and linked these to the vital ability to measure time. This framework can be used in a variety of ways such as structuring the development of assessment interviews, but may also be helpful in a more holistic approach to the way in which the curriculum documents and teacher planning incorporate this important topic.

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