Burny, E. Valcke, M. & Desoete A., (in press). Towards an Agenda for Studying Learning and Instruction Focusing on Time-Related Competences in Children. Accepted for publication in *Educational Studies*. 35(5). Approximate publication date December 2009.

Towards an Agenda for Studying Learning and Instruction Focusing on Time-Related Competences in Children

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Since the 1920ies researchers have been studying children's temporal concepts, concluding that the concept of time is complex and difficult to teach children (Fraisse 1984 et al. 1999; Piaget 1969; Zakay 1989). This research literature review aims to provide a theoretical framework to guide future research about time-related teaching in primary school. After preliminary considerations about the potential of instructional interventions in this context, this review analyzes the position of time related conceptions within primary school curricula and explores which factors exert an influence on the concept of time. Finally, clock reading is discussed as a key time-related skill in primary education that mirrors the complexity of time conceptions in general.

Introduction

Time is a vital structuring element in today's society. It determines the planned nature of economics, politics, culture, communication, etc. Time has been studied from a variety of perspectives, such as archeology, geography (Hägerstrand 1970), informatics (Abraham and Roddick 1999), artificial intelligence (Allan 1983), logic (Augusto 2001), mathematics (Liu and Xiang 2008) and history (Schmitt 2005), resulting in various definitions of this concept.

Within this review, time is defined as a component of a measuring system used to sequence events, to compare the duration of events and the intervals between them. Time-related competences are then seen as the competences and skills associated with measuring and recording the passage and duration of time e.g. clock reading, using calendars and timelines, measuring time intervals, etc.

Despite the fact that time is described as a complex concept that is difficult to grasp by children, the development of time-related competencies in individuals – such as children or youngsters – has received only limited systematic attention (Block 1989; Fraisse 1984; Kelly et al. 1999; Piaget 1969; Zakay 1989). This is especially critical when it comes to the research of evidence-based practices in this particular field of the primary school curriculum.

The present literature review aims at developing a scientific framework to ground the study of instructional practices in view of the development of time related competences in primary school children.

Development versus instruction

Research of children's understanding of time has been initiated by developmental psychologists, resulting in a number of influential theories that emphasize the natural course in children's development (Friedman 1982; Levin and Gilat 1983; Piaget 1969; Siegler and Richards 1979). More recently, the research literature concentrates rather on an educational perspective, stressing the role of learning and instruction in the acquisition of time related competences (Hodkinson 2004;.Dawson 2004; Hoodless 2002; van Galen and Peltenburg 2008)

Piaget's theory about the development of time related competences

According to Piagetian theory, young children only understand time as it is related to velocity, space and movement, because they cannot perceive duration in a direct way (Bourdillon 1994; Harner 1981; Hoodless 2002; Levin and Gilat 1983; Piaget 1969; Richie and Bickhard 1988). This basic assumption is reflected in Piaget's methodology to investigate the development of time conceptions. Children are asked to make judgments about duration when comparing the elapsed travel time of two trains, varying in terms of starting point, point of arrival, speed, and distance covered. (Richie and Bickhard 1988).

Piaget states that cognitive development is to be seen as an autonomous construction process through adaptation and equilibration mechanisms. Piaget recognizes the additional role of learning processes to foster development, but states that cognitive development can never be the outcome of learning that is invoked by instructional processes (Brainerd 1978). Building on this premise, developmental psychologists have mainly focused on defining age-related developmental stages, describing children's gradual developing understanding of the time concept (Bentley 1987; Siegler and Richards 1979).

Piagetian theories criticized

Piaget's theory has been hugely influential, but has been found inadequate in a number of ways. First, the developmental stages are too rigid. A significant number of studies have found that young children can acquire concrete operational thinking at an earlier age as proposed, and also that they can think at a higher level as suggested by Piaget (Fraisse 1982; Muijs and Reynolds 2005; Richie and Bickhard 1988). Stevenson and Pollit (1987) point out that this underestimation of children's ability can be attributed to the inappropriateness of the tasks given to children.

Other researchers criticize Piaget's underestimation of individual, social and cultural differences between children (Donaldson 1979), and the importance of a child's interaction with the environment (Bruner 1973; Inhelder 1962; Wadsworth 1996). Piaget neglected cross-cultural differences, while many researchers have found that growing up in a different culture results in distinct cognitive temporal structures that reflect differences in time related conceptions, perceptions and attitudes (Anderson and Brodowsky 2001; Anderson and Venkatesan 1994; Bearden, Money and Nevins 2006; Brodowsky and Anderson 2000; Brodowsky, Granitz and Anderson 2008; Levine 1988, 1997; Levine and Wolff 1985; Van Auken, Barry and Bagozzi 2006).

Notwithstanding the critical voices, the Piagetian conceptions remain useful to look at children's development (Muijs and Reynolds 2005). But, from an educational point of view, Piagetian theory presents an incomplete picture.

Educational perspectives on the acquisition of time related competences

Recently, research has moved away from age-related models to understand time conceptions of children and rather stresses the importance of learning and instruction (Stow and Haydn 1999), concluding that pupils ability in the area of time really depends upon instruction (Lee, Ashby and Dickinson 1996; Stow and Haydn 1999; Thornton and Vukelich 1988). The latter implies that time conceptions should be explicitly addressed, and taught in a systematic way (Hodkinson 1995; Westman 1987).

The central role of instruction is also supported by cross-cultural research: due to the fact that time related competences are a more prominent component in the Chinese curriculum as compared to the United States, Chinese children are two years ahead on US children in solving of complex time, speed and distance related problems (Zhou, Peverly and Lin 2004).

The former clearly suggests that the role of instructional interventions is not to be underestimated. However, little research is available about instructional interventions that promote children's development of time-related competences.

Time in the primary school curriculum

Children's ability to comprehend time does not develop as an isolated cognitive competency, but relies on a list of emerging skills including numeracy, literacy, memory, and spatial abilities (Foreman et al. 2007). As a result, time is incorporated in a variety of elementary school subjects: history (chronology), mathematics (mechanical time), geography (deep time) and literacy (time-related vocabulary).

History learning builds on the understanding of time related concepts, such as chronology, a sense of period and the active use of a specific vocabulary (Bourdillon 1994; Dawson 2004; Haydn, Arthur and Hunt 1997; Hoodless 1996). Various instructional strategies have been employed to enhance children's chronological thinking skills, but most share a common representation to teach chronology: the timeline (O'Hara and O'Hara 2001; Smart 1996). Alternative representations might build on the potential of information and communication technologies (Cooper 2000; O'Hara and O'Hara 2001; Wood and Holden 1995; Yaxley 2004).

However, time conceptions are basically related to the field of ***mathematics*** and intimately connected with the well-known representations and symbol systems, such as clocks, calendars, lunar cycles, time tables, etc. (Kelly et al. 1999). Time is basically situated within the domain of measurement (figure1) and involves the teaching of analog and digital clocks, writing and reading the date, to determine durations, to use time-tables, etc. (AEC 1994;

NCTM 2000; Ontario Mathematics Curriculum 2005; QCA 1999; QSA 2004). We return to clock reading later in this review.

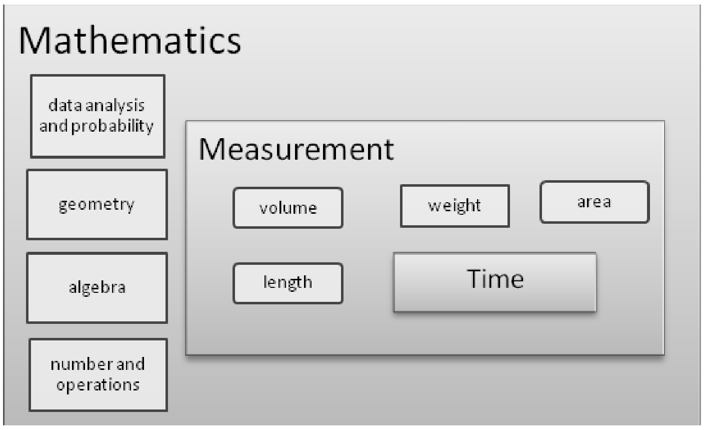

Figure 1 the place of time in mathematics education

According to Walsh' theory of magnitude (2003), time, space and number are part of a general magnitude system , which presumes a connection between time and other mathematical domains such as number and geometry.

Geography, for its part, involves the concept of "deep time". If and how this abstract notion should be taught in primary school is debated but yet there has little been researched in relation to the design of curricular materials (Trend, 2002).

Since time is a basic human experience, all natural ***languages*** have developed a rich repertoire to express temporality (Harner 1981; Klein 1994). In order to represent, to think about, or to solve time-related problems, children develop a time-specific vocabulary (Harner 1981; Hoodless 2002). Primary school curricula adopt the concept of time in language in subjects as defining time order in stories, organizing ideas, sentence fluency, using timelines, using the correct tenses in grammar, etc. (Ontario Language curriculum 2005; QCA 1999) The use of children's books as an instructional strategy has been found to promote the development of children's time-related vocabulary and understanding of time and chronology

(Hoodless 2002), because children learn to see and to make time connections through stories (Fox 1993).

The impact of specific instructional interventions

The adoption of instructional programs and practices in the field of time related competences seems rather driven by ideology, faddism, politics and marketing than by empirical evidence (Slavin 2008), resulting in a variety of teaching methods and a lack of evidence-based practices (Muijs and Reynolds 2000; Stevenson and Baker 1991).

First, differences in teaching practices can be found in the adopted instructional paradigm (Case 1998; Daniels and Shumow 2003; De Corte 2004; Ellis and Berry 2005; Van de Walle 2007). The adoption of (1) a traditional approach (e.g. emphasis on rules, memorizing and rehearsing); (2) a structuralist approach that stresses abstract conceptualizations of mathematical content or (3) a realistic view towards learning and teaching mathematics presenting problems within a familiar context in order to give meaning, will affect the design of learning materials and the instructional strategies suggested in textbooks (Carnine, Dixon, and Silbert 1998; Van de Walle 2007). This has been researched in an extensive way in relation to mathematical subdomains, such as number concept, calculation, word problems, etc., but hardly in the field of the development of time related competences (Barry 2005; Cooper 1993; Ellis and Askey 1999; Jiang 1995; Nathan et al. 2002).

Second, differences between the instructional interventions and curricula are found in the timing and the stage at which the time related conceptions are presented to children as well as in the kinds of learning opportunities provided and in its organizing and sequencing (Schmidt et al. 1997).

Clock reading as an important time-related skill

As pointed out earlier, pursuing time is well integrated into the primary school curriculum. The most exclusive time-related subject in primary school, playing a role in nearly every grade of primary school, is clock reading.

Sub-competences in clock reading

Telling time is a complex and important cognitive skill that is required on a daily basis (Bock et al. 2003; Friedman and Laycock 1989). Due to the engagement of a complex of interrelated sub-competences in this skill, it takes teachers years to teach their pupils to read and write clock times. These sub-competences have received little attention in research about the teaching and learning of time conceptions but it can be assumed that clock reading builds upon mathematical, visuospatial and linguistic sub-competences and requires the development of cognitive-conceptual representations.

Mathematics A variety of mathematical knowledge and skills is needed in order to be able to tell the time. Firstly, clock reading builds on number sense and the ability to count. Secondly, a basic understanding of fractions is needed to appreciate the division of the clock face into halves and quarters. Finally, measuring time-intervals, requires adding and subtracting skills.

Language Time-telling requires speech planning and the development of a time-specific vocabulary, including the – arbitrary – rules for telling and writing the time (Korvorst, Roelofs and Levelt 2007). Speech planning involves (1) conceptual preparation (determining a reference point),(2) lemma retrieval and syntax (selection of corresponding lemma’s) and (3) form encoding. Two linguistic formats are frequently used in time-telling: the relative and the absolute system (Bock et al. 2003; Williams 2004). Relative expressions, e.g., ten past two, mention the relationship between an hourly reference point and the minute, and put the minute before the hour. Absolute expressions, e.g. two ten, do not require a reference point and put the hour before the minute.

Visuospatial aspect The visuospatial aspect of the clock is mainly discussed within research literature on clock drawing as a screening task for cognitive impairment in the elderly and more specific for the assessment of dementia (Brodaty and Moore 1997; Cahn and Kaplan 1997; Huntzinger et al. 1992; Tuokko et al. 1992; Watson 1993) and for children with developmental dyslexia or ADHD (Eden, Wood and Stein 2003; Kibby, Cohen and Lynd 2002). Since performance on mathematics and in visuospatial working memory have shown to be related (Henry and macLean 2003; Kyttälä et al. 2003, 2008), visuospatial perception is assumed to play a role in the ability to read the clock but there was no research literature found on this subject. Further research is needed to determine the role of visuospatial perception and memory in clock reading skills.

Cognitive conceptual representations Children need some additional conceptual knowledge in order to give meaning to the clock: they need to develop a sense for the duration of an hour, a minute and seconds and have to learn how these durations relate to each other and are related to their personal embodied experience of what an hour, a minute or a second feels like (Van de Walle 2007; Williams 2004). This helps to develop rich cognitive conceptual representations of time (Wilkening and Druyan 1987).

Acquisition of clock reading skills

Despite the importance of time-telling, few studies are available studying the development of the time-telling competency (Williams 2004). Nevertheless, available studies show that the ability to tell time from analog clocks develops in a particular order, which can however vary across countries depending on the nature of the instructional program.

When do children learn to tell time?

At the age of 4 years, few American children can do more than recognize and label the hour that is linked to salient activities such as bedtime, eating, etc. About one-third to half of 5 year olds can read the hour and by the age of 6 most are able to read the hour correctly. In second grade (7-8 years of age), readings the hour and the half hour is nearly correct in all children. In third grade, the error margin is about 5-minutes and in fourth grade has reduced to one-minute (Williams 2004). During fifth grade, little improvement is observed in analog clock reading skills (Andersson 2008; Case, Sandieson, and Dennis 1986; Friedman and Laycock 1989; Siegler and McGilly 1989; Vakali 1991, Williams 2004). Whereas reading analog clocks is experienced as quite difficult, digital clock reading is acquired in a much faster way (Williams 2004). Most children are as a result able to read both analog and digital clocks correctly at the age of 8 to 10 years (Case et al. 1986; Friedman and Laycock 1989; Siegler and McGilly 1989; Vakali 1991).

What strategies do children use in time-telling?

A confined number of studies focused on the strategies children use to read the time. Friedman and Laycock (1989) point out the need of different strategies for reading the clock, operating on clock times and understanding the meaning of time. Moreover, strategies differ for analog and digital clocks because of the difference in representation of time.

Clock reading strategies The reading of digital displays seems mainly a matter of retrieving these number values and labels, which results in direct reading of the displayed time (Williams 2004). Analog clocks represent hours and minutes on a continuum on which numerical values and related intervals have to be interpreted as discrete steps, and make higher cognitive processing demands (Friedman and Laycock 1989). Two strategies are distinguished in the reading of analog clock times: immediate recognition, building on the immediate retrieval of the cognitive scheme linked to e.g. the position of both hands on the clock, and counting, which is spontaneously used by young children to measure the duration of events (Levin and Wilkening 1989; Wilkening, Levin, and Druyan 1987).

Strategies to operate on clock times Digital clocks mainly require numerical addition and subtraction to read the time (Friedman and Laycock 1989; Wiliams 2004). Analog clocks require visuo-spatial strategies: imaginary movements of e.g., the minute clock hand are used to add or subtract time intervals. Children also have to be able to select and apply the correct operation in view of clock reading. This demands additional mathematical insight.

Understanding the meaning of time Children develop an understanding of time conceptions by linking them to salient activities in their lives. Within the primary classroom, conventional time and calendar systems provide children with a consistent set of units to use for this purpose (Kellyt al. 1999).

Clock reading instruction

For years, teachers have observed students' frustration as they grappled with learning to read an analog clock and have felt frustrated not knowing how to help (Monroe et al 2002). Teachers of young children generally concur that their students learn mathematical concepts best when they construct understanding through concrete experiences (Liljedahl 2002). Unfortunately, time is difficult to experience in the classroom since it cannot be felt, seen or heard.

Williams (2004, 2008), found that children make meaning from a clock through *guided conceptualization*: teachers use gestures and speech to annotate the clock face while guiding students through the process of time telling. As pointed out earlier, there’s a lack of evidence-based practices in time teaching so teachers rely on different methods for teaching clock reading skills as presented in textbooks (Van de Walle 2007).

Masterman and Rogers (2002) point out the importance of *scaffolding* - using various kinds of learning materials to facilitate learning - in children's acquisition of and reasoning with abstract concepts such as time. The tools used in the teaching of clock reading skills have however remained similar for many years but may not be sufficient for developing children's understanding since they focus on telling time, not on developing concepts of time (Monroe et al. 2002). With the increasing use of multimedia in the classroom, new possibilities have arisen in the field of clock reading (Masterman and Rogers 2002).

Discussion

In the past, research on time concepts in children has mainly focused on when children acquire certain time-related competences such as clock reading (e.g. Piaget 1969; Friedman 1982; Levin and Gilat 1983). This gives an idea of how children develop their understanding of time but reveals little on the underlying cognitive processes. Despite its continuously pointing out the complexity of time concepts and the difficulties involved for children, research never got into a full consideration of what makes the concept of time so complex for children to grasp.

A deeper understanding of the complexity of time concept is needed in order to determine how this concept should be taught to children in primary school. On the basis of this review a conceptual framework (figure2) can be developed, underlining and clearing out the complexity of time concept by representing all aspects involved in the understanding of time. However, further research is needed in order to determine the relations between these aspects.

Research on time concepts has revealed that next to a developmental factor, learning and instruction does play an important role in children's evolving understanding of time (Lee, Ashby and Dickinson 1996; Stow and Haydn 1999; Thornton and Vukelich 1988). Unfortunately, for many years research on time concepts has been focusing on other domains than learning and instruction, resulting in a lack of evidence-based methods in the teaching of time concepts to primary school children. Especially this lack of evidence-based methods is an area for further research, since primary school teachers are rather insecure about their skills in teaching time. Revealing the complexity of the time concept is a first step in the search for evidence-based methods in the teaching of time concepts.

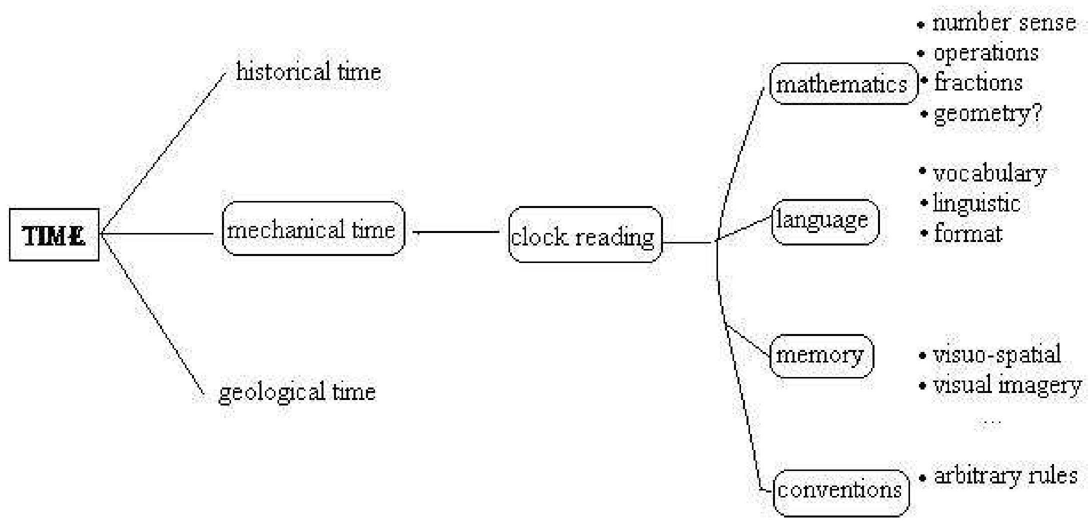

Figure 2. Conceptual framework

References

Abraham, T. and J.F. Roddick. 1999. Survey of spatio-temporal databases. *Geoinformatica.* 3: 61-9

Ado, A. O. 1989. Difficulties experienced by primary four pupils in solving word problems. PhD Diss. University of Lagos.

Allan, J.F. 1983. Maintaining knowledge about temporal intervals. *Communications Of the ACM*. 26: 832-43

Anderson, B.B. and G.H. Brodowsky. 2001. A cross-cultural study of waiting as a satisfaction driver in selected service encounters. *Journal of East West Business.* 7: 11-36

Andersson, U. 2008. Mathematical competencies in children with different types of learning difficulties. *Journal of educational Psychology.* 100: 48-66

Askey, R. 1999. Knowing and teaching elementary mathematics. *American Educator*. 23: 12–13

Augusto, J.C. 2001. The logical approach to temporal reasoning. *Artificial intelligence review*. 16: 301-33

Australian Education Council (AEC). 1994. *Mathematics – A curriculum for Australian schools.* Carlton: Curriculum Corporation

Bentley, A.M. 1987. Swazi children's understanding of time concepts: a Piagetian study. *Journal of genetic psychology.* 148: 443-52

Bock, K., D.E. Irwin, D.J. Davidson and W.J.M. Levelt. 2003. Minding the clock. *Journal of Memory and Language.* 48: 653–85.

Bourdillon, H. 1994. *Teaching history.* London: Routledge

Brainerd, C. J. 1978. *Piaget's Theory of Intelligence*. New Jersey: Prentice Hall, Inc

Brodaty, H. and C.M. Moore. 1997. The Clock Drawing Test for dementia of the Alzheimer's type: A comparison of three scoring methods in a memory disorders clinic. *International Journal of Geriatric Psychiatry*. 12: 619–27.

Brodowsky, G.H. and B.B. Anderson. 2000. A cross-cultural study of consumer attitudes toward time. *Journal of global marketing.* 13: 93-103

Cahn, D.A. and E. Kaplan. 1997. Clock drawing in the oldest old. *Clinical Neuropsychologist.* 11: 96–100

Carnine, D., R. Dixon and J. Silbert. 1998. Effective strategies for teaching mathematics. In *Effective teaching strategies that accommodate diverse learners,* ed. E. Kameenui and D. Carnine, 93-112. Columbus, OH: Merrill

Case, R. 1998. Changing views of knowledge and their impact on educational research and practice. In D. Olson,& N. Torrance (Eds.), *Handbook of education and human development*. 75–99. Malden, MA: Blackwell.

Case, R., R. Sandieson and S. Dennis. 1986. Two cognitive developmental approaches to the design of remedial instruction. *Cognitive Development.* 1: 293–333.

Cooper, H. 2000. *The teaching of history in primary schools: implementing the revised national curriculum.* London: David Fulton Publishers

Cooper, P.A. 1993. Paradigm shifts in designed instruction: From behaviorism to cognitivism to constructivism. Educational Technology 33: 12-19.

Daniels, D.H. and L. Shumow. 2003. *Child development and classroom teaching: a review of the literature and implications for educating teachers.* Applied developmental psychology, 23: 495-526

Dawson, I. 2004. Time for chronology? Ideas for developing chronological understanding. *Teaching history.* 117: 14-24

De Corte, E. 2004. Mainstreams and perspectives in research on learning (mathematics) from instruction. *Applied psychology: an international review*.53: 279-310

Donaldson, M. 1979. *Children's minds*. New York Norton

Eden, G.F., F.B. Wood and J.F. Stein. 2003. Clock drawing in developmental dyslexia. *Journal of learning disabilities*. 36: 216-28

Ellis, M.W. and R.Q. Berry. 2005. The paradigm shift in mathematics education: explanations and implications of reforming conceptions of teaching and learning. *The mathematics educator.* 15: 7-17

Foreman, N., S. Boyd-Davis, M. Moar, L. Korallo and E. Chappell. 2007. Can virtual environments enhance the learning of historical chronology? *Instructional science.* 36: 155-73

Fox, C. 1993. *At the very edge of the forest: the influence of literature on storytelling by children.* London: Cassell

Fraisse, P. 1982. The adaptation of the child to time. In *The Developmental Psychology of Time*, ed. W.J. Friedman, 113-140. New York: Academic Press

Fraisse, P. 1984. Perception and estimation of time. *Annual review psychology.* 12: 1- 36

Friedman, W. J. 1982. Conventional time concepts and children's structuring of time. In *The Developmental Psychology of Time*, ed. W.J. Friedman, 171-208. New York: Academic Press

Friedman, W.J. 1990. *About time: inventing the fourth dimension*. Cambridge, MA:MIT Press

Friedman, W.J. 2000. The development of children's knowledge of the times of future events. *Child development.* 71: 913-32

Friedman, W.J. and F. Laycock. 1989. Children's analog and digital clock knowledge. *Child Development.* 60: 357-71

Hägerstrand, T. 1970. What about people in regional science? *Papers regional science association.* 24: 7-21

Harner, L. 1981. *Children's understanding of time.* Topics in language disorders. 2:51-65

Henry, L.A. and M. MacLean. 2003. Relationships between working memory, expressive vocabulary and arithmetical reasoning in children with and without intellectual disabilities. *Educational and Child Psychology.* 20: 51–64.

Hodkinson, A.J. 1995. Historical time and the national curriculum, *Teaching History.* 79: 18-20

Hoodless, P.A 2002. An investigation into children's developing awareness of time and chronology in story. *Journal of Curriculum Studies.* 34: 173-200

Hoodless, P.A. 1996. *Time and timelines in the primary school.* London: Historical Association

Huntzinger, J. A., R.B. Rosse, B.L. Schwartz, L.A. Ross and S.I. Deutsch. 1992. Clock drawing in the screening assessment of cognitive impairment in an ambulatory care setting: A preliminary report. *General Hospital Psychiatry.* 14: 142–44.

Inhelder, B and J. Piaget. 1962. *The growth of logical thinking*. New York: Basic Books

Jiang, Z. 1995. A brief comparison of the U.S. and Chinese middle school mathematics programs. *School Science and Mathematics*. 95: 187–94.

Kelly,M.K., K.F. Miller, G. Fang, and G. Feng. 1999. When days are numbered: calendar structure and the development of calendar processing In English and Chinese. *Journal of Experimental Child Psychology.* 73: 289–314

Kibby, M.Y., M.J. Cohen and G.W. Hynd. 2002. Clock face drawing in children with attention-deficite / hyperactivity disorder. *Archives of clinical neuropsychology*. 17: 531-46

Klein, W. 1994. *Time in language*. London: Routledge

Korvorst, M., A. Roelofs and W.J.M. Levelt. 2007. Telling time from analog and digital clocks. *Experimental psychology.* 54: 187-191

Kyttälä, M. 2008. Visuospatial working memory in adolescents with poor performance in mathematics. *Educational psychology.* 28: 273-89

Kyttälä, M., P. Aunio, J. Lehto, J. Van Luit and J. Hautamäki. 2003. Visuospatial working memory and early numeracy. *Educational and Child Psychology.* 20: 65–76.

Lee, P., R. Ashby and A. Dickinson. 1996. Progression in children's ideas about history. In *Progression in learning*, ed. M. Hughes, 50-79. UK: multilingual matters

Levin, I. and I. Gilat. 1983. A developmental analysis of early time concepts: the equivalence and additivity of the effect of interfering cues on duration comparisons of young children. *Child development.* 54: 78-83

Levin, I., and F. Wilkening. 1989. Measuring time via counting: the development of children's conceptions of time as a quantifiable dimension. In *Time and human cognition: a life-span perspective*, ed. I. Levin and D. Zakay, 119-144. Amsterdam: North-Holland.

Levine, R.V. 1997. *A geography of time*. New York: Basic Books

Levine, R.V. and E. Wolff. 1985. Social time: the heartbeat of culture. *Psychology today.* 19: 28-35

Liljedahl, P. 2002. Embodied experience of velocity and acceleration: a narrative. *Journal of mathematical behavior.* 20: 439-445

Liu, H.B. and X. Xiang. 2008. A class of the first order impulsive dynamic equations on time scales. *Non linear analysis-theory methods and applications.* 69:2803-11

Masterman, E. and Y. Rogers. 2002. A framework for designing interactive multimedia to scaffold young children's understanding of historical chronology. *Instructional science.* 30: 221-241

Muijs, D. and D. Reynolds. 2000. School effectiveness and teacher effectiveness in mathematics: some preliminary findings from the evaluation of the mathematics enhancement programme (Primary). *School effectiveness and school improvement.* 11: 273-303

National Council of Teachers of Mathematics (NCTM). 2000. Principles and standards for school mathematics. Reston: NCTM

Nathan, M.J., S.D. Long and M.W. Alibali. 2002. Symbol precedence in mathematics textbooks: a corpus analysis. *Discourse processes*. 33: 1-21

Nelson, K. 1996. *Language in cognitive development: emergence of the mediated mind*. Cambridge UK: Cambridge University Press

O'Hara, K. and M. O'Hara. 2001. *Teaching history 3-11: the essential guide.* London: Continuum

Ontario Ministry of Education. 2005. *The Ontario Curriculum Grades 1-8. Mathematics.* Ontario: Ministry of Education. *http://www.edu.gov.on.ca.*

Piaget, J. 1969. *The child's conception of time.* New York: Ballentine

Piaget, J. 1970. *The child's conception of movement and speed*. New York: Ballantine

Qualifications and Curriculum Authority (QCA). 1999. *The national curriculum for England.* London: qualifications and curriculum authority

Queensland Studies Authority (QSA). 2004. *Mathematics, years 1 to 10 syllabus.* Queensland: Queensland Studies Authority

Richie, D.M. and M.H. Bickhard. 1988. The ability to perceive duration: its relation to the development of the logical concept of time. *Developmental psychology.* 24: 318-323

Schmidt, W.H., C. McKnight, G.A. Valverde, R.T. Houang and D. Wiley. 1997. *Many visions, many aims: a cross-national investigation of curricular intentions in school mathematics.* Dordrecht: Kluwer

Schmitt, J.C. 2005. Time – "impense" of history or double objective of the historian? *Cahier de civilization medievale.* 48: 31-52

Siegler, R. S. and K. McGilly. 1989. Strategy choices in children's time-telling. In *Time and human cognition: A life-span perspective,* ed I. Levin & D. Zakay. 185–218. Oxford, England: North-Holland.

Siegler, R.S. and D.D. Richards. 1979. Development of time, speed and distance concepts. *Developmental Psychology*. 15: 288-98

Slavin, R.E. 2008. Perspectives on evidence-based research in education. *Educational researcher*. 37: 5-14

Smart, L. 1996. *Using I.T. in primary school history.* London: Cassell

Smith, P.E. 1987. *One Hand at a Time. Using a One-Handed Clock To Teach Time-Telling Skills. Primary Grades.* U.S.: Dale Seymour Publications

Stevenson, D.L. and D.P. Baker. 1991. State control of the curriculum and classroom instruction. *Sociology of education.* 64: 1-10

Stevenson, R.J. and C. Politt. 1987. The acquisition of temporal terms. *Journal of child language*. 14: 533-545

Stow, W. and T. Haydn. 1999. Issues in the teaching of chronology. In *Issues in History Teaching,* ed. J. Arthur & R. Phillips. 83-97. London, Routledge

Thornton, S.J. and R. Vukelich. 1988. Effects of children's understanding of time concepts on historical understanding. *Theory and research in social education*. 16: 69-82

Trend, R.D. 2002. Developing the concept of deep time. In *Global science literacy,* ed. V.J. Mayer. 187-201. Netherlands: Kluwer Academic Publishers

Truscott, J.B., A. Boyle, S. Burkill, J. Libarkin, J. Lonsdale. 2006. The concept of time: can it fully be realized and taught? *Planet.* 17: 21-23

Vakali, M. 1991. Clock time in seven to ten year-old children. *European Journal of Psychology of Education*. 6: 325–36.

Van Auken, S., T.E. Barry and R.P. Bagozzi. 2006. A cross country construct validation of cognitive age. *Journal of the academy of marketing science*. 34: 439-55

Van de Walle, J.A. 2007. Elementary and middle school mathematics teaching developmentally. *Boston: Pearson education.* 6th ed.

Van Galen, F. and M. Peltenburg. 2008. *Tijd en tijdsbeleving, klokkijken wijzer voor wijzer.[Time and time experience, clock reading, one hand at a time]*. Utrecht: Freudenthal Instituut.

Wadsworth, B.J. 1996. *Piaget's theory of cognitive and affective development*. New York: Longman

Walsh, V. 2003. A theory of magnitude: common cortical metrics of time, space and quantity. *TRENDS in cognitive sciences.* 7: 483-88

Watson, Y.I. 1993. Clock completion: An objective screening test for dementia. *Journal of the American Geriatrics Society.* 41: 1235–40.

Westman, A.S. 1987. Development of time concepts: differentiating clock and calendar from apparent durations. *Journal of genetic psychology*. 148: 259-270

Wilkening, F., I. Levin and S. Druyan. 1987. Children's counting strategies for time quantification and integration. *Developmental psychology.* 23: 823-831

Williams, R.F. 2004. Making meaning from a clock: material artifacts and conceptual blending in time-telling instruction. PhD Diss. University of California, San Diego.

Williams, R.F. 2008. Guided conceptualization? Mental spaces in instructional discourse. In *Mental spaces in discourse and interaction,* ed. T. Oakley and A. Hougaard. 209-234. Amsterdam: John Benjamins

Yaxley, J. 2004. Experiencing history. *Teaching history*. 42: 24-25

Zakay, D. 1989. Subjective time and attentional resource allocation: an integrated model of time estimation. In *Time and human cognition: a life-span perspective*, ed I. Levin & D. Zakay. 365-397. Amsterdam: North Holland.

Zhou, Z., S.T. Peverly and C. Lin. 2004. Cross- and within- cultural variations in children's understanding of distance, time and speed interrelationships: a follow-up study. *Journal of Genetic Psychology*. 165: 5-27