Development of metacognitive skills in young adolescents : a bumpy ride to the high road

Stel, M. van der

Chapter 1

General introduction

In the last decades, young adolescents, when entering secondary school, increasingly have been placed in the role of active learners with responsibilities for their own learning process. In the Netherlands, this resulted in a secondary-education system in which students have to face more and more responsibilities for their own learning and study success. In order to be successful, students have to be able to plan their learning activities and execute them in a systematic and orderly way, to monitor and to evaluate their own learning and to reflect on it. All afore-mentioned skills are components of metacognitive skillfulness.

This thesis aims to gain insight into the development of metacognitive skillfulness in young adolescents. The development of metacognitive skills will be investigated in relation to intellectual ability and learning performance. Furthermore, it will be investigated whether metacognitive skills are general or domain specific. Metacognitive-skill development of young adolescents, aged 12 to 15 years, will be investigated in both longitudinal and cross-sectional designs.

1.1 Metacognition as a concept

In recent publications *metacognition*, that is, cognition about cognition, has been characterized as a concept that lacks coherence (Veenman, Van Hout-Wolters, & Afflerbach, 2006) and as a concept with 'fuzzy borders' (Zohar & Ben-David, 2009). Besides the problem that the concept of metacognition is not very well-defined, the term metacognition often is used interchangeably with self-regulation (SR) and self-regulated learning (SRL), or considered as intertwined with self-regulation (Dinsmore, Alexander, & Loughlin, 2008; Fox & Riconscente, 2008). SR and SRL are concepts that are rooted in the social-cognitive research tradition and influenced by neobehaviorism, while metacognition has its roots in cognitive developmental research. SR emphasizes the interaction of the person with the environment as well as the motivation of the person (Bandura, 1977). The application of SR to school learning led to the SRL-theory. According to SRL-theory, the interaction between cognition, metacognition, and motivation is very important for learning performance (Zimmerman, 1986). In cognitive developmental studies, however, researchers traditionally are less concerned with the role of motivation in learning. The research in this thesis is conducted from a cognitive developmental perspective and will focus on metacognition in particular.

One of the reasons for the lack of consensus concerning the term *metacognition* is that it is used to refer to both knowledge about cognition and to regulation of cognition. In most descriptions of metacognition two knowledge components can be distinguished: A declarative knowledge component and a procedural knowledge component for the regulation of behavior (Brown, 1987; Schraw & Moshman, 1995; Veenman et al., 2006). Flavell (1976, 1979), as 'founding father' of metacognition, subdivided metacognition into metacognitive knowledge and the active monitoring and regulation of cognitive processes: "Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, (…) Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects on which they bear, usually in the serve of some concrete goal or objective." (Flavell, 1976, p. 232). According to Flavell, metacognitive knowledge refers to the declarative knowledge one has about the interplay between person characteristics, task characteristics, and strategy characteristics. For example, a student thinks that s/he is a poor performer (person characteristic) in remembering historical facts and dates (task characteristics) and, therefore, has to write down the important facts and dates several times (strategy characteristics) before knowing them by heart. Procedural metacognitive knowledge is known from the literature by terms of 'executive decisions' (Kluwe, 1987), 'metacognitive control' (Ertmer & Newby, 1996), 'regulation and control' (Brown, 1987; Schraw, 1998), and 'metacognitve skills' (Veenman, 1993). All these terms refer to a person's *skills* for regulating and controlling his/her own cognitive activities. Metacognitive skills refer to the actual regulation of, and control over, one's learning performance (Brown & DeLoache, 1978; Veenman, Elshout, & Meijer, 1997). In many cases, however, metacognitive skills remain covert mechanisms that take place inside the head (Veenman et al., 2006) and have to be inferred from students' overt behavior or utterances, that is, from concrete cognitive activities. For example, when a student starts to reread a paragraph, this activity is probably the consequence of a monitoring or evaluation process. Different components of metacognitive skillfulness (also referred to as 'subscales of metacognitive skillfulness') may come into play either at the onset of task performance (orientation), during task performance (planning, monitoring, evaluation), or at the end of task performance (elaboration and reflection). A more detailed description of metacognitive skills, in particular those in text studying and problem solving, is given in section 1.5.

Some researchers not only separate declarative from procedural knowledge, but they also distinguish conditional knowledge (Brown, 1987; Schraw & Moshman, 1995), resulting in a distinction between a) declarative metacognitive knowledge (knowing that, knowing about); b) conditional metacognitive knowledge (knowing when and why); and c) procedural metacognitive knowledge, also referred to as metacognitive skills (knowing how). Conditional knowledge, however, pertains to declarative knowledge. Even if conditional knowledge is adequate, it does not guarantee the right application of a certain strategy due to the fact that the learner does not necessarily possess the procedural knowledge of *how* to use this strategy (Veenman, 2011). In order to apply metacognitive skills in the right way at the right time, one needs the required repertoire of procedural knowledge, that is, knowing *how* to use these skills effectively. This repertoire can be considered as a program of self-instructions (Veenman, 2011), represented by a production system of condition-action rules (Anderson, 1996; Veenman, 2011; Winne, 2010). The condition part of the rules triggers certain activities (i.e., the action part of the rules) of the learner. For example, IF (condition) you cannot solve the problem on which you are working, THEN (action) see if you can transform it into a familiar problem; or IF (condition) you encounter an unfamiliar word, THEN (action) see if you can deduce its meaning from the context, and if not, look it up in a dictionary. Considering metacognitive skills as condition-action rules implicates that students can be trained to use the condition and the action part as one set of rules belonging to a production system of metacognitive self-instructions within a certain context. Once students recognize the condition part of the rules, they will perform the action part of the rules that is triggered by the conditions. Some of these actions will be automated when students become more experienced learners, others need to be consciously applied and tuned to the task at hand (Veenman, 2011). Finally, Zohar and Ben-David (2009) refer to the 'how, when & why' knowledge as meta-strategic knowledge (MSK), which links MSK to Kuhn's procedural meta-knowing (1999). According to Veenman (2011), MSK "obscures the boundary between metacognitive knowledge and skills. It precludes the notion that metacognitive strategies may fail either due to incorrect or incomplete conditional knowledge, or due to lack of knowledge about how to execute a strategy" (p. 199). Nevertheless, conditional knowledge can be considered as an important factor in the acquisition of metacognitive skills. Knowing when and why to use a certain strategy can be considered as a first step toward the acquisition of metacognitive skills, that is, the cognitive stage of production rules before these rules get transformed into automated skills through proceduralization. Proceduralization is the dropping out of cues from declarative knowledge, resulting in a faster and more automated execution of the strategy (Anderson, 1996).

As stated above, metacognitive declarative knowledge refers to factual knowledge one has about the cognitive system in general and one's own cognition in particular. Like knowledge about other things, one's knowledge about the cognitive system can have shortcomings. It can be insufficient, inaccurate, not reliably retrieved, etc. (Flavell, 1992). Conditional knowledge is declarative knowledge about when and why certain metacognitive strategies should be applied. Although some researchers (Schraw &

Moshman, 1995; Simons, 1996) assumed that metacognitive knowledge is correct knowledge based on earlier experiences, it can be argued that metacognitive knowledge, just like any other type of declarative knowledge, is not always correct, available and/or applied when necessary. As Campione (1987, p. 134) formulated: "Availability of knowledge, either declarative or procedural, does not in itself guarantee flexible access to and use of those resources". Alexander, Carr and Schwanenflugel (1995) found a discrepancy between children's knowledge about monitoring and applying monitoring skills during task performance. Winne (1996) stated that knowledge has no effect on behavior until this knowledge is actually needed and actually used. So, it is quite possible that students have knowledge of a certain strategy at their disposal, but still not spontaneously use this strategy during task performance (Barnett, 2000; Focant, Grégoire, & Desoete, 2006; Pressley, Yokoi, Van Meter, Van Etten, & Freebern, 1997; Veenman, Kok, & Blöte, 2005). According to the findings of the afore-cited studies, metacognitive (conditional) knowledge does not automatically lead to an adequate use of metacognitive strategies. Consequently, metacognitive knowledge often poorly predicts learning outcomes, whereas metacognitive skills appear to have a much stronger predictive value (Veenman, 2005). Based on a review of studies, Wang, Haertel, and Walberg (1990) concluded that metacognition is the most important predictor of learning performance. In an overview of studies, Veenman (2008) estimated that metacognitive skillfulness accounted for 40% of variance in learning performance. Therefore, this thesis will focus on metacognitive skills in relation to learning performance.

1.2 Metacognition from a developmental perspective

Roughly spoken, research into the development of metacognition has focused on two issues: 1) Where does metacognition come from? And 2) when does it first emerge and how does it develop from there? Although the question 'where does metacognition come from?' is an issue of great interest, this issue goes beyond the scope of this thesis. Therefore, it will be discussed only very briefly. Some evidence has been found that "theory of mind" (ToM) can be considered as a precursor of metacognitive knowledge (Lockl & Schneider, 2006), while metacognitive knowledge can be considered as a necessary precursor of one's metacognitive skills (Annevirta & Vauras, 2006). In both studies, metacognitive competencies of very young children (preschoolers) were assessed. Results of both studies indicate that individual differences in the development of these competencies are already existent at an early age.

In this thesis the focus will be on the discussion about the second issue, the developmental trajectory of metacognition, in particular of metacognitive skills.

According to Piaget (Inhelder & Piaget, 1958), children younger than seven years are not able to keep a record of their own problem-solving attempts due to shortcomings in storing a record of their own cognitive activities. Piaget claimed that the egocentrism of young children prevents them from introspection or treating their own thinking as an object (Flavell, 1992). He assumed that egocentric perspective would change at the age of 11 – 12 years "when the child moves into thinking characterized by formal operations or hypothetico-deductive reasoning. Now the child becomes capable of metacognition in the sense of awareness of and reflective knowledge regarding her own thoughts and thought processes" (Piaget, 1964/1968, p. 64).

The earliest work on metacognitive development, however, dealt almost exclusively with metamemory, that is, awareness and monitoring of memory strategies. Evidence was found that children younger than 11 – 12 years have knowledge or at least awareness of their own memory and memory-strategy use. Flavell, Friedrichs, and Hoyt (1970) investigated the ability to predict one's own immediate memory span in preschool through fourth grade students. Results showed strong developmental differences. Accuracy in predicting the memory span increased significantly with age. In a longitudinal study between 2 and 20 years, Schneider and Pressley (1997) found evidence that memory-strategy development begins before elementary school and continues into adulthood. Furthermore, older children predict their own (memory) performance better than preschoolers, who often overestimate their own performance (Flavell & Wellman, 1977). Despite the fact that preschoolers display some metacognitive knowledge, (e.g., they understand that increasing the number of items makes a memory test harder; Kreutzer, Leonard, & Flavell, 1975), it is not before middle childhood that they understand that a memory strategy like categorization of objects will help them remember the objects better (Moynahan, 1978). Furthermore, young children tend not to apply strategies spontaneously in contexts where they would be useful. Improvements in this respect occur during the middle childhood years, but even by the end of childhood (strategy use or memory) performance is far from infallible (Brown et al., 1983; Schneider, 1985). Not only in the field of metamemory evidence was found against Piaget who related the onset of metacognition to the formal-operational stage of development (11 – 12 years). Researchers in other domains (e.g., problem solving and text comprehension) also found evidence of metacognitive activities in younger children, even preschoolers. Kluwe (1987) investigated how children of different ages could cope with changing problem-solving conditions. Results showed that 4-year-olds knew when an originally selected approach to the problem was no longer adequate. These young children appeared to be able to effectively regulate their own search for a solution. Whitebread et al. (2009) observed 3- to 5-year olds while interacting in playful problem-solving situations, e.g., distributing dolls over a limited number of chairs. The children revealed elementary forms of planning, monitoring, and reflection. Markman (1979) investigated elementary school children's awareness of their own comprehension failure by presenting them inconsistent information. Results showed that third through sixth graders do not spontaneously carry out the monitoring processes that they are capable of. Only modest improvements could be observed through the school years. If the students were alerted that something in the passage might not make sense, Markman found that the performance of sixth graders exceeded that of third graders. Veenman et al. (2006) argue that it is most likely that metacognitive skills develop alongside metacognitive knowledge during preschool and early-school years at a very basic level and that these skills become more sophisticated and academically oriented when needed in formal educational settings. In a cross-sectional study, Veenman et al. (2004) investigated the metacognitive skillfulness of fourth-, sixth-, and eighth-graders, and university students (aged 9 – 22 years). When performing four inductive-learning tasks in different domains, students' metacognitive skillfulness was assessed with logfile analysis and thinking-aloud protocols. A linear increase of metacognitive skillfulness with age was found. In the same vein, Veenman and Spaans (2005) assessed the metacognitive skillfulness of first-year and third-year secondary school students performing a problem-solving task in math and an inductive-learning task in biology. Veenman and Spaans (2005) found that high-intelligent students exhibited more metacognitive activities relative to low-intelligent ones, while third-year students showed more metacognitive activities than first-year students did.

From the afore-cited it becomes clear that metacognition develops gradually, that is, it does not appear from one moment to the other like a rabbit from a magician's hat. As Kuhn (2000, p. 178) formulated: "metacognition emerges early in life, … and follows an extended developmental course during which it becomes more explicit, more powerful, and hence more effective, as it comes to operate increasingly under the individual's conscious control." In order to understand better how metacognitive development can be facilitated, it is important to know more about the developmental trajectory of metacognition. As could be learned from the afore-cited studies, the development of metacognition is quite a long trajectory. It appears that even very young children exhibit metacognitive competencies to a certain extent (Brown, 1997), while the metacognition of adults still reveals serious weaknesses (Kuhn, Garcia-Mila, Zohar, & Anderson, 1995). As stated earlier, Brown et al. (1983) and Schneider (1985) found that children not always apply strategies spontaneously in contexts where they would be useful. Kuhn (1999) said that not a great deal is known about the development of metastrategic (memory) skills in school contexts. Therefore, the focus in this thesis is on spontaneous use of metacognitive skills, without any training or intervention, during the performance of ecologically valid school tasks.

One of the weaknesses of research on metacognitive development so far is the frequent use of cross-sectional designs. Despite the risk of participants dropping out from a longitudinal study before data collection has ended, there are serious arguments in favor of a longitudinal design relative to a cross-sectional design. In a longitudinal design continuous changes in frequency and quality of metacognitive skillfulness can be detected and followed with more precision than in a cross-sectional design. Moreover, in a cross-sectional design there is the problem of error variance due to comparing different age groups. Given the large individual variability in brain structure among individuals, especially during development, Casey, Tottenham, Liston, and Durston (2005) advocate a more frequent use of longitudinal designs in evaluating cortical changes with age. Considering the pros and cons of the two designs, for this thesis a longitudinal design is preferred to the more frequently used “cross-sectional, frozen, one shot looks at age changes” (Brown, 1987, p. 107) design.

1.3 Metacognitive skills and intellectual ability

Veenman (1993; Veenman & Beishuizen, 2004; Veenman, Elshout, & Meijer, 1997; Veenman & Verheij, 2003) described three, mutually exclusive models concerning the relation between intellectual ability and metacognitive skillfulness as predictors of learning performance. The *intelligence* model regards metacognitive skillfulness as an integral part of intellectual ability. In this model metacognitive skillfulness does not contribute to learning performance on top of intellectual ability. According to this model, metacognitive skills cannot have a predictive value for learning performance independent of intellectual ability. Sternberg (1990), for instance, advocates such an inclusive position of ‘metacomponents’ in his triarchic theory of intelligence. Support for the intelligence model was found by Elshout and Veenman (1992) in a study with university students working in a computer-simulated environment. Other researchers found significant differences concerning the application of metacognitive strategies between gifted and non-gifted students (Cheng, 1993; Hannah & Shore, 1995; Shore & Dover, 1987; Span & Overtoom-Corsmit 1986; Zimmerman & Martinez-Pons, 1990). The second, contrasting model is the *independency* model, in which intellectual ability and metacognitive skillfulness are regarded as entirely independent predictors of learning performance. Support for the independency model was found by Allon, Gutkin, and Bruning (1994). They found a correlation of .15 between metacognition scores and WISC-R scores of adolescents performing several cognitive tasks. In a study with children performing Piagetian tasks, Swanson (1990) reported that intelligence and metacognition were unrelated. In another study, however, Swanson, Christie, and Rubadeau (1993) found that metacognition appeared to be only partly independent of intelligence. In the third model, the *mixed* model, intellectual ability and metacognitive skillfulness are correlated, but metacognitive skillfulness has its own, unique contribution to the prediction of learning performance, on top of intellectual ability. Support for the mixed model was found in several studies, either with computer simulations in the domains of physics, statistics, and behavioral psychology, with text-studying tasks in the domains of law, geography, or with problem-solving tasks in the domains of math, biology and physics (Elshout &Veenman, 1992; Veenman, 1993; Veenman & Beishuizen, 2004; Veenman & Elshout, 1991, 1999; Veenman, Elshout, & Busato, 1994; Veenman, Elshout & Meijer, 1997; Veenman, Prins, & Elshout, 2002; Veenman & Spaans, 2005; Veenman & Verheij, 2003; Veenman, Wilhelm, & Beishuizen, 2004). Results of a study in which primary-school students performed arithmetic problems (Van der Heijden, 1989) corroborated the mixed model as well. The same applied for the results of Maqsud (1997) with secondary-school students performing math and reading tasks. Berger and Reid (1989) concluded from their study with students ranging from mentally retarded to normal achieving individuals that "IQ mediates metacognition, but does not explain it". Stankov (2000) argued that metacognition is partly independent of fluid intelligence. Minnaert and Janssen (1999), on the other hand, rejected the intelligence model, but could not decide between the independency model and the mixed model when predicting first-year university students' learning performance, while using a questionnaire to measure regulatory study activities.

Although over the last decades support has been found for each of the three models, the results of studies with complete data sets, that is, data sets containing measures of metacognition, intelligence, and learning performance, seem to be in favor of the mixed model. Most of the studies, however, are difficult to compare due to dissimilarities in methods for assessing metacognitive skillfulness (thinking aloud, observation, questionnaires), in participants (age, educational background, intelligence), and in tasks and domains. Another limitation for comparing the studies concerns the fact that the focus of some studies is restricted to the relation between intellectual ability and metacognitive skillfulness, thereby excluding the relation of both predictors with learning performance. Moreover, many of the afore-cited studies concern university students, that is, students who are used to apply their metacognitive skills in an academic context for quite a period of time. Because of these limitations, it still remains uncertain whether the mixed model can be generalized to younger students with less developed metacognitive skills. From a developmental perspective not only the question to what extent intellectual ability and metacognitive ability are related as predictors of learning performance is interesting, but also the question how both predictors develop in relation to each other. Alexander et al. (1995) formulated three developmental hypotheses with regard to the relation between intellectual ability and the development of metacognition, excluding the relation of both predictors with learning performance. The *ceiling* hypothesis assumes that effects of intelligence on the development of metacognition diminish over time. Initially, gifted children might develop their metacognitive skills faster than non-gifted children, but later the non-gifted children 'catch up'. In line with the *ceiling* hypothesis, Schneider and Pressley (1997) argue that during cognitive development the effects of some limitations of the information processing system in young children, for example their memory capacity, are being reduced. This would result in more resources becoming available with age for applying metacognitive skills. Conversely, the *acceleration* hypothesis assumes that the impact of intelligence on the development of metacognition increases with age. If this were the case, intellectual development would reinforce the development of metacognitive skills. When regulatory activities demand more complex and/or more abstract activities with age (e.g. reflecting), a higher intellectual level is required to do so. At the same time one could argue that more complex cognitive tasks require more and better metacognitive skills. Finally, the *monotonic* development hypothesis assumes that both intelligence and metacognition show a monotonic growth over age, while intellectual ability does not affect the development of metacognitive skills. Linking the models proposed by Alexander et al. (1995) to the three models described by Veenman (1993), it can be argued that both the acceleration hypothesis and the ceiling hypothesis relate to the intelligence model as the influence of intellectual ability on metacognition either increases or diminishes with age. In the ceiling hypothesis the intelligence model will fit less with age, whereas in the acceleration hypothesis the intelligence model will fit more with age. The monotonic hypothesis, on the other hand, predicts a parallel growth of both intellectual and metacognitive abilities. Such a parallel, monotonic development requires that the development of metacognition does not interact with the intellectual development, as would be the case in a non-monotonic development. The monotonic development hypothesis would suggest a link with the mixed model, where metacognitive skills do not develop merely as a component of intellectual ability, but have their own unique contribution to learning performance on top of intellectual ability. Finally, the independency model fits none of Alexander's hypotheses, since it predicts that there is no relation between intelligence and metacognition at all. In their literature overview, Alexander et al. (1995) found support for the monotonic development of metacognitive knowledge. Gifted children showed a general superiority in their declarative metacognitive knowledge. Giftedness effects were persistent throughout childhood with gifted early elementary school children showing a similar superiority in this knowledge relative to their non-gifted peers as junior high school students did. With regard to metacognitive skills, however, the results were inconclusive. Alexander et al. (1995) did not address intellectual and metacognitive ability as predictors of learning performance. In several studies, Veenman (2006), Veenman and Spaans (2005), and Veenman et al. (2004) addressed this issue using inductive discovery-learning tasks or problem-solving tasks in a cross-sectional design. Overall results fitted the mixed model. Metacognitive skills develop alongside, but not entirely as part of intellectual ability. Moreover, support was found for a monotonic maturation effect of both intellectual ability and metacognitive skillfulness in a parallel mode across age groups.

In this thesis not only participants' intellectual and metacognitive abilities will be assessed each year for three consecutive years, but also their learning performance. In this way, the relation between intellectual ability and metacognition as predictors of learning performance will be addressed and at the same time the relation between the first two variables will be studied from a developmental perspective. After entering secondary school young adolescents will perform two series of different tasks in two widely varying domains for three consecutive years.

1.4 Generality vs. domain-specificity of metacognitive skills

A frequently discussed issue is whether metacognitive skills are domain specific or general by nature. Prior studies concerning this issue of metacognitive skills being general or domain specific have yielded contradictory results. By using four metacognitive tasks (ease of learning judgments, feeling of knowing judgments, judgments of learning, and text-comprehension monitoring), Kelemen, Frost, and Weaver (2000) investigated whether university students' metacognitive monitoring ability is a general, domain-independent ability. They concluded that metacognitive memory accuracy was not stable across tasks and sessions, which they interpreted as evidence against a general metacognitive ability. Also Glaser, Schauble, Raghavan, and Zeitz (1992) found evidence against the generality of metacognitive skills. They investigated the generality vs. domain-specificity of metacognition in discovery-learning tasks. University freshmen performed three discovery-learning tasks in different domains (physics and economics).

Results showed that metacognitive activities of university students varied across different discovery-learning tasks, which can be interpreted as evidence in favor of domain specificity. Nevertheless, Glaser et al. (1992) did not rule out the role of general strategies of a larger grain size, since learners improved when performing one learning task after the other. In a study of Veenman et al. (1997), metacognitive skills of students performing discovery-learning tasks in three different domains (calorimetry, statistics, and a fictitious one) appeared to be general rather than domain specific. In another study (Veenman et al., 2004), the metacognitive skillfulness of fourth-, sixth-, and eighth-graders, and university students appeared to be a general, person-related characteristic for all age groups, ranging from 9 to 22 yrs. All participants performed four computerized inductive-learning tasks, that is, two tasks in the domain of biology and two tasks in the domain of geography. In Veenman and Verheij (2003), technical university students performed two tasks, a mathematical model-construction task that was part of their curriculum and a discovery-learning task in a fictitious domain. Their results supported the generality of metacognitve skills across tasks and domains. Veenman and Beishuizen (2004) found support for the general nature of metacognitive skills of undergraduate students studying two texts in different domains (geography vs. forensic psychology). Schraw, Dunkle, Bendixen, and Roedel (1995) investigated the nature of metacognitive skills, in particular monitoring skills, during test taking. In a first experiment, Schraw and colleagues (1995) found support for the domain-specific hypothesis. In this experiment, they used eight tests that differed with respect to several dimensions, like content, length, difficulty, and test format. In a next experiment, tests were used that differed only on one dimension, that is, only content domain was varied. Once tests were matched on dimensions other than content knowledge, findings were consistent with the domain-general hypothesis. Schraw et al. (1995) suggested a compromise between domain-specific and domain-general hypotheses. They argued that "domain-general monitoring skills emerge late in development, are preceded by modularized monitoring skills, and emerge only after considerable effort has been devoted…to integrating monitoring skills across domains" (p. 441). In the same vein, Veenman and Spaans (2005) assumed that metacognitive skills initially develop on separate islands of tasks and domains and that after the age of 12 years these metacognitive skills become more and more general. In their study, 12- and 15-year olds performed two tasks in two different domains (solving math word problems and an inductive-learning task for biology). Metacognitive skills of the 12-year-olds appeared to be rather domain specific, whereas those of the 15-year-olds turned out to be general. It can be argued that in the afore-cited studies differences in tasks and domains were not large enough in order to answer the question whether metacognitive skills are general or domain specific by nature, and whether age is involved. By maximizing the difference in both tasks and domains at the same time, the opportunity for finding a domain-specific factor will be optimized, relative to prior studies in which domains and/or tasks differed to a lesser extent. Therefore, in the research for this thesis, history vs. mathematics are contrasted as domains because they additionally allow for a substantial difference in tasks, that is, text studying vs. problem solving. Moreover, both tasks are ecologically valid as all students are to a certain extent familiar with and trained in these domains since elementary school. In a longitudinal design in which the same participants are followed for several years, it also is possible to draw conclusions about the nature of metacognitive skills along the developmental trajectory. The question is whether metacognitive skills will develop from being domain specific into general skills, as argued by Schraw et al. (1995) and Veenman & Spaans (2005).

1.5 Metacognitive skills in text studying and problem solving

Many studies on metacognitive skills pertain to one particular domain or task. Presumably, the most frequently used tasks are problem-solving tasks and text-studying or text-comprehension tasks. As shown in section 1.4, there is still no consensus among researchers whether metacognitive skills are general of domain specific. As argued by Veenman et al. (2006, p. 7), “one of the reasons for these equivocal results may be found in the grain of analysis used by researchers. At first glance, metacognitive activities may differ from one task to the other, say text studying vs. problem solving”. In a hierarchical model three levels of specificity of metacognitive activities were distinguished for any task (Meijer, Veenman & Van Hout-Wolters, 2006). Based on a very detailed list (Pressley & Afflerbach, 1995) of some 150 concrete metacognitive reading activities, Meijer et al. (2006) made a list of some 65 metacognitive activities for problem-solving tasks in physics. Activities in the detailed list of Pressley and Afflerbach as well as in the one of Meijer et al. can be considered as metacognitive activities at the lowest level. Looking at metacognitive activities in different tasks, they could be perceived as different from task to task. At the surface level, they differ indeed, but they stem from the same metacognitive behavior at the intermediate level. For example, prior to the actual reading of a history text, a student may scan the subtitles of all paragraphs in order to get an idea about what the text is about, while prior to a math problem, s/he will make a sketch of the problem in order to build a mental representation of the problem. In both cases, the student applies a metacognitive skill that guides the initial execution of the task, that is, the preparatory activity of orienting on the task prior to execution. Other examples of orienting activities for text-studying tasks are scanning the text, goal setting for reading, and thinking about what to expect in an upcoming test (Pressley & Afflerbach, 1995; Veenman & Beishuizen, 2004). Examples of orienting activities for problem-solving tasks are reading the problem statement, establishing what information is given and what is asked for, and predicting a plausible outcome (Meijer et al., 2006). Like the orienting activities, concrete planning activities for text-studying tasks also differ from planning activities for problem-solving tasks at the lowest level. For example, deciding what to read first and how to navigate through the text pertains to text-studying tasks, while designing a step-by-step action plan in order to solve the problem is distinctive of problem-solving tasks. In short, concrete, task-specific self-regulatory activities at the lowest level have a common denominator at the intermediate level. In this thesis, four components of general metacognitive skillfulness are distinguished at the intermediate level: *Orientation*, that is, preparatory metacognitive activities prior to task performance; *Planning,* that is, having an orderly sequence of planned actions instead of working by trial- and-error; *Evaluation*, that is, monitoring and checking in order to keep track of good task performance; *Elaboration and Reflection*, that is, reflecting on what has been learned, and relating this to one's own prior knowledge. These four components have been based on the *Effective working method* by Veenman (1993), which is an organized set of self-regulatory activities for passing through the phases (prior, during, and after) of task performance. Each of these activities not only seems to contribute to good task performance, but they also appear to be highly interdependent (Veenman & Spaans, 2005). When orienting thoroughly on a task, a student probably will build a deeper representation of the problem or the task requirements. Consequently, the student will be able to build a detailed plan instead of working by trial-and-error, which further enables him/her to monitor and control the learning process. Finally, this set of activities provides an opportunity for learning through reflection (Veenman et al., 1997). As formulated in section 1.4, the difference in both tasks and domains in this thesis is maximized relative to other studies, in order to answer the question whether metacognitive skills are general or domain specific by nature. By maximizing the difference in both tasks and domains at the same time, the opportunity for finding a domain-specific factor will be optimized. Because the scores at the intermediate level are composed of scores at the lowest level, scores at the intermediate level allow for finding both general and domain-specific tendencies. In the case of metacognitive skills being general by nature, there has to be a stability in *intra-individual* differences across different tasks in different domains. For example, if a student is metacognitively active in text studying, s/he will show this active metacognitive behavior in problem solving too. If metacognitive skills would be domain specific by nature, however, no stability in intra-individual differences across tasks would be found. Thus, a student that is metacognitively active in text studying, not necessarily will show the same metacognitve behavior in problem solving.

1.6 Assessing metacognitive skills

In the past decades, different methods for assessing metacognitive skills have been developed. These methods differ regarding the way and the moment the assessment takes place. With respect to the way of assessing metacognitive skills, a main distinction is made between off-line and on-line methods (Veenman et al., 2006). Off-line methods are assessment methods that are used before or after task performance. Questionnaires (e.g., MSLQ, Pintrich & De Groot, 1990; MAI, Schraw & Dennison, 1994) and interviews (Zimmerman & Martinez-Pons, 1990) are examples of off-line methods. Both questionnaires and interviews can be administered before (prospective) or after (retrospective) task performance (Veenman, 2005). On-line methods, on the other hand, are concurrent methods. In these methods the assessment of metacognitive skills takes place during task performance. Systematic observations (Veenman et al., 2005; Whitebread et al., 2009), think-aloud protocol analysis (Azevedo, Greene, & Moos, 2007; Pressley & Afflerbach, 1995; Veenman, 1993; Veenman & Spaans, 2005), and computer logfile registrations (Hadwin, Nesbit, Jamieson-Noel, Code, & Winne, 2007; Veenman et al., 2004) are examples of on-line methods. The essential difference between off-line and on-line methods is that off-line methods measures merely rely on self-reports from the learner, whereas on-line measures concern the coding of learner behavior on externally defined criteria (Veenman, 2011). Studies with multi-method designs have shown that off-line measures hardly correspond to on-line measures. In a review study, Veenman (2005) found hardly any correspondence between off-line self-reports and various on-line assessment methods. In the same vein, Hadwin et al. (2007, p. 119) reported that "self-reports were poorly calibrated with actual traceable studying events" during text studying in G-Study, a computerized reading environment. Cromley and Azevedo (2006) also compared off-line and on-line methods. Three parallel strategy-use measures were administered to a sample of 30 ninth-grade students: a prospective self-report measure (Metacognitive Awareness of Reading Strategies Inventory, MARSI), a concurrent multiple-choice measure which required students to apply the strategies to specific passages, and students were asked to think aloud during text studying. Two measures of reading comprehension, a standardized measure and free recall scores, were collected as well. Results showed that the concurrent multiple-choice and think-aloud data were both significantly correlated with the comprehension scores and with each other, whereas the prospective self-report data had non-significant correlations with all of the other measures. Cromley and Azevedo (2006) recommended using concurrent measures to study strategy use in reading comprehension. On-line methods appear to be more predictive of learning performance relative to off-line methods (Bannert & Mengelkamp, 2008; Sperling, Howard, Miller, & Murphy, 2002; Veenman, 2005). In his review study, Veenman (2005) found that correlations with learning performance range from slightly negative to .36 for off-line measures, and from .45 to .90 for on-line measures. The external validity of on-line measures appears to be better than that of off-line measures. Furthermore, low convergent validity among off-line self-report measures, and high convergent validity among different on-line measures are reported (Veenman, 2005). The relatively high convergent and external validity of online-measures for metacognition led to the use of online-measures in this thesis. In case of thinking aloud, students verbalize their actual, ongoing thoughts during task performance. This requires not only a certain level of (language) development of the students, but also a certain level of task difficulty. If the task is very easy, cognitive processes will be automated and ongoing thoughts will not be verbalized. If the task is too complex, students probably will fall silent. Therefore, if students are quite young or the task is not suitable, the obtained protocols will be rather shallow, that is, incomplete and not very well elaborated. Considering the fact that participants in this thesis are old enough to verbalize their own thoughts, that the tasks are suitable for their age, and that both quantitative and qualitative scores are required, the think-aloud method was appropriate for research in this thesis. Having students thinking aloud during task performance makes it possible to measure metacognitive behavior in the most direct way. Studies by Bannert and Mengelkamp (2008), Ericsson and Simon (1993), and Veenman, Elshout, and Groen (1993) show that using the think-aloud method neither affects the learning process, nor learning performance. Bannert and Mengelkamp interpret this as indirect evidence that thinking aloud does not interfere with metacognition, and therefore, they recommend this type of verbalization as an online-assessment method (2008, p. 54). Veenman (1993) compared students' logfile measures with think-aloud protocols. Results showed that thinking aloud does not interfere with metacognitive processes, although it may slow down those processes a bit.

1.7 Objectives and expectations of this thesis

The first objective of this thesis is to establish whether metacognitive skills will increase in frequency/quantity (QN) and quality (QL) during early adolescence. Based on prior studies (Veenman et al., 2004; Veenman & Spaans, 2005), a linear growth in both the quantity and quality of metacognitve skillfulness is expected. The second objective relates to the development of the relation between metacognitive skills and intellectual ability as predictors of learning performance. It is expected that metacognitive skills develop alongside, but not fully dependent on intellectual ability, in line with the mixed model (Veenman, 1993) and the monotonic development hypothesis (Alexander et al., 1995). As a third, and last objective, the generality vs. domain-specificity of metacognitive skills is investigated over age. In line with results of Veenman and Spaans (2005), it is expected that metacognitive skills tend to generalize along the developmental trajectory.

1.8 Outline of this thesis

In this first chapter (Chapter 1), a theoretical background of the empirical studies conducted as part of this thesis has been given. The four chapters (Chapters 2-5) that report about the empirical studies examined metacognitive skillfulness in young adolescents aged 12 – 15 years. In Chapters 2 – 4, results for each year of a three-year-longitudinal study are reported. Chapter 5 describes the results of a cross-sectional study. The first year of the longitudinal study (Chapter 2), however, is limited to the first two research questions as formulated in section 1.7. Since there were no data of other years available in the first year of the longitudinal study, in Chapter 2, the two main issues were to establish whether metacognitive skills have their own, unique contribution to learning performance on top of intellectual ability, and whether metacognitive skills are general or domain-specific. Chapter 3 and 4 share all three research question (see section 1.7). Since the cross-sectional study (Chapter 5) was restricted to the domain of mathematics, the third research question concerning the generality vs. domain-specificity of metacognitive skills had to be left out. In Chapter 6 some methodological issues are discussed that could not be fully addressed in the articles due to limited space. Finally, in Chapter 7, the findings described in the Chapters 2 – 5 are summarized and discussed. Chapters 2 – 5 have been published in, or submitted to peer-reviewed journals.

To acknowledge the contributions of the co-authors the full references are presented below:

- Van der Stel, M., & Veenman, M.V.J. (2008). Relation between intellectual ability and metacognitive skillfulness as predictors of learning performance of young students performing tasks in different domains. *Learning and Individual Differences, 18*, 128-134. (Chapter 2)

- Van der Stel, M., & Veenman, M.V.J. (2010). Development of metacognitive skillfulness: A longitudinal study. *Learning and Individual Differences,20*, 220-224. (Chapter 3)
- Van der Stel, M., & Veenman, M.V.J. (submitted). Metacognitive skills and intellectual ability of young adolescents: A longitudinal study from a developmental perspective. (Chapter 4)
- Van der Stel, M., Veenman, M.V.J., Deelen, K., & Haenen, J. (2010). The increasing role of metacognitive skills in math: A cross-sectional study from a developmental perspective. *ZDM The International Journal of Mathematics Education, 42*, 219-229. (Chapter 5)