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

Stel, M. van der

Chapter 3

Development of metacognitive skillfulness: A longitudinal study

Abstract

This study shows the results of a two-year longitudinal study where the same participants were followed for two consecutive years as they enter secondary school (aged 12 – 14 years). The main issue was to investigate the development of both the quantity and the quality of metacognitive skills. Another issue was to establish whether the development of metacognitive skillfulness is intelligence-related or relatively intelligence-independent. Finally, the generality vs. domain specificity of developing metacognitive skillfulness was investigated. Thirty-two secondary-school students participated in this study. While thinking aloud they performed two different tasks representing two different domains: A text-studying task for history and a problem-solving task for math. Participants' intellectual ability, metacognitive skillfulness and learning performance were assessed. Results show a quantitative as well as a qualitative growth in metacognitive skillfulness. Furthermore, results of both years show that metacognitive skillfulness contributed to learning performance (partly) independent of intellectual ability. A parallel development of metacognitive and intellectual ability was found. Finally, metacognitive skills predominantly appear to be general. Domain-specific metacognitive skills, however, played a substantial, but minor role as well in both years. Instructional implications are being discussed.

3.1 Introduction

Since Flavell (1979) introduced the concept 'metacognition', many studies have addressed the issue of the influence of metacognition on learning performance. Based on a review of studies, Wang, Haertel, and Walberg (1990) concluded that metacognition is the most important predictor of learning performance. Our study focuses on the development of metacognitive skills: What components develop when? Is the development of metacognitive skills dependent on (or part of) the development of intellectual ability? Are developing metacognitive skills general or domain specific by nature. Answers to these questions could contribute to our understanding of the development of metacognitive skills and the educational consequences.

3.1.1 Metacognitive skillfulness

Metacognitive skills concern the *procedural* knowledge that is required for the actual regulation of, and control over one's learning activities (Brown & DeLoache, 1978; Veenman, Elshout, & Meijer, 1997). Metacognitive skills can be inferred from overt behavior or utterances by the student, i.e., from concrete metacognitive activities. Examples of metacognitive activities are given in Table 3.1.

Several studies (Bowen, Shore, & Cartwright, 1992; Brown, 1980; Christoph, 2006; Markman, 1977, 1979; Mevarech & Fridkin, 2006; Pressley & Afflerbach, 1995; Schoenfeld, 1992; Shore & Lazar, 1996) have focused on the use of metacognitive skills while performing different tasks (e.g., reading comprehension or problem solving). This study, however, includes both problem-solving and text-studying tasks focusing on both the quantity (frequency of applying metacognitive skills) and the quality of these skills (the depth, e.g., drawing a conclusion in one's own words is considered as a deeper elaboration than summarizing almost literally). In line with Veenman, Wilhelm, and Beishuizen (2004), we expect metacognitive skills to increase in frequency as well as in quality over the years (hypothesis 1).

A related research issue is whether the development of metacognitive skills is intelligence-related or relatively intelligence-independent. Several researchers (Alexander, Carr, & Schwanenflugel, 1995; Borkowski & Peck 1986; Schneider & Pressley, 1997; Veenman & Spaans, 2005; Veenman, et al., 2004) investigated metacognitive skills in relation to intellectual ability.

3.1.2 Relation between intellectual ability, metacognitive skills, and learning performance from a developmental perspective

Veenman (Veenman & Beishuizen, 2004; Veenman et al., 1997) described three models concerning the relation between intellectual ability and metacognitive skillfulness as predictors of learning performance. Over the last decades, support has been found for each of these models (for an overview, see Veenman & Spaans, 2005; Veenman et al., 2004). The evidence found so far seems to be highly in favor of the *mixed model*. In this 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. Because many studies concerned the metacognitive skillfulness of older students, it remains to be ascertained more thoroughly whether the mixed model can be generalized to younger students with initially developing metacognitive skills. Furthermore, the role of intellectual ability in the *development* of metacognitive skills will be addressed in this study. Alexander et al. (1995) formulated three developmental hypotheses with regard to the relation between intelligence and the development of metacognition. The *monotonic development hypothesis* assumes that both intelligence and metacognition show a monotonic growth over age. Finding such a parallel development would support the monotonic development hypothesis. We hypothesize that metacognitive skillfulness develops alongside, but not fully dependent on intellectual ability, regardless of tasks and domains. Therefore, we expect to find a parallel development of metacognitive skillfulness and intellectual ability *as predictors* of learning performance in line with the mixed model and the monotonic development hypothesis (hypothesis 2).

3.1.3 Metacognitive skillfulness across domains

Another objective of this study was to establish whether metacognitive skillfulness is general, or domain specific. From a developmental and an instructional perspective, it is relevant to know how metacognitive skills develop: Whether they develop from being general into becoming domain specific or the other way around? Earlier studies yielded contradictory results (Schraw, Dunkle, Bendixen, & Roedel, 1995; Schraw & Nietfeld, 1998; Veenman & Beishuizen 2004; Veenman & Verheij 2003; Veenman et al., 1997, 2004; De Jong, 1992; Glaser, Schauble, Raghavan, & Zeitz, 1992).

Based on earlier studies, the onset of metacognitive *skill* development for academic tasks is not to be expected before the age of 8-10 years (Alexander et al., 1995; Berk, 2006; Kuhn, 1999; Siegler, 1998). The academic metacognitive skills of 12-year olds are still premature and developing, which may explain why these skills may diverge on notably different tasks (Veenman & Spaans, 2005). Participants in the present study are rather young and inexperienced in applying academic metacognitive skills. Therefore, we expect their metacognitive skills to be in a transitory phase of development. We hypothesize that the participants will initially use general as well as domain-specific metacognitive skills. We also hypothesize that the initially acquired domain-specific metacognitive skills tend to generalize during further development. Therefore, we expect older students to resort less to domain-specific metacognitive skills than younger students (hypothesis 3).

3.2 Method

3.2.1 Participants

In the first year of this longitudinal study, 32 first-year secondary school students (12 boys, 20 girls; average age 12 years and 8 months) participated. They were selected on their intellectual ability from 85 students of a school in the Netherlands (section 3.2.3). This school is known because of its large diversity of children, thus representing a broad educational level of the students, a broad range of social economic status of parents, and various ethnic backgrounds. We have chosen not to work with more than one school in order to avoid confounding variables, such as differences in teachers, pedagogical/didactic philosophy, schoolbooks, etc. Students with learning or conduct disorders (e.g., dyslexia or ADHD) were excluded from the study. In the second year we lost four students due to changing residence. The remaining 28 students (10 boys, 18 girls; average age 13 years and 8 months) participated in the second year.

3.2.2 Metacognitive skillfulness

Thinking-aloud protocols were analyzed according to the procedure of Veenman (Prins, Veenman, & Elshout, 2006; Van der Stel & Veenman, 2008; Veenman & Beishuizen, 2004;). Metacognitive skillfulness was divided into four subscales: Orientation (O), Planning and Systematic orderliness (P), Evaluation (Ev), and Elaboration (El). In Table 3.1 general metacognitive activities across both tasks and domains and more specific metacognitive activities for text studying and problem solving are described (Meijer, Veenman, & Van Hout-Wolters, 2006; Pressley, 2000; Pressley & Afflerbach, 1995).

Table 3.1 Examples of domain-specific and general metacognitive activities

	History-specific	Math-specific	General
Orientation			
a.			Activating prior knowledge
b.			Goal setting
c.	Predicting the content of the text	Estimating the answer	
d.	Reading titles of paragraphs prior to reading the entire text	Making a sketch of the problem in order to represent the problem	
Planning & Systematic orderliness			
a.			Subgoaling
b.			Time management
c.	Designing a reading plan and deciding upon which text parts to pay attention to	Designing a step-by-step action plan, instead of working by trial-and-error	
d.	Note taking (self-instruction for doing so)	Writing down calculations step by step	
Evaluation			
a.			Expressing non-understanding
b.			Comment on own activities
c.	Monitoring text comprehension during reading	Monitoring action plan	
d.	Self-correction after rereading (parts of) the text	Checking an answer by recalculating	
Elaboration			
a.			Recapitulating and drawing conclusions
b.			Relating the answer to the question or problem
c.	Paraphrasing (parts of) the text	Paraphrasing the problem	
d.	Summarizing (self-instruction for doing so); Making inferences during reading	Drawing conclusions while referring to the problem statement	

The scoring method consisted of two steps. First, an utterance was coded in the margin if belonging to one of the subscales (O, P, Ev or El). This resulted in a quantitative score obtained by counting the frequency of metacognitive activities on each subscale. Secondly, a score for the quality of metacognitive skillfulness was judged from the protocols. To obtain a reliable score for the quality of metacognitive skillfulness, scoring criteria were formulated. A five-point scale (ranging from 0 to 4)[4] was used to score the quality of each subscale.

In both years, 6 protocols of each task were rated by two judges separately. Since the inter-rater reliability[5] was high, the remaining protocols were analyzed and rated by one judge.

3.2.3 Intellectual ability

In both years, intellectual ability was assessed. Three subtests from the Groninger Intelligence test for Secondary Education (GIVO, standardized Dutch intelligence test; Van Dijk & Tellegen, 1994) were selected: Number Series, Verbal Analogies and Unfolding Figures. A fourth test (Names & Professions, requiring the memorization of word pairs; Veenman & Beishuizen, 2004) was added to assess memory abilities. In both years, the intellectual ability score was obtained by transforming the scores on each test into z-scores and then calculating the mean z-score for each participant.

3.2.4 Tasks

To ensure the novelty of tasks, each year participants were given *new* tasks with task demands adapted to their age. All tasks were piloted beforehand. In order to allow domain-specific metacognitive activities, the differences in tasks and domains were maximized.

3.2.4.1 History task

In an individual session of 50 minutes, participants were asked to study a history text in the same way as they usually do when preparing for a test. They were also asked to read and think aloud. Participants were allowed to study the text for 30 minutes. In the remaining 20 minutes the post-test was administered (section 3.2.5). In both years, three activating questions or assignments were embedded in the text. These were not meant for testing the students' knowledge, but to elicit (more) metacognitive activities. From a

[4] Results of a CatPCA show that it is permitted to treat the scores for metacognitive skills as interval variables.

[5] The mean inter-rater reliability score for math and history for both years was .90.

pilot-study (Meijer, Veenman, & Van Hout-Wolters, 2006) we learned that if a text does not contain such activating questions, many participants just tend to read linearly.

3.2.4.2 Mathematics task

In another thinking-aloud session of 50 minutes, participants practiced to solve mathematical word problems in 20 minutes. Together with the assignments, participants received a sheet containing the answers and a brief stepwise explanation of how to solve the problems. Participants were free to consult this sheet whenever and as much as they liked. The first 20 minutes were considered as a learning-by-doing phase. Next, the participants handed in all materials and received another series of parallel problems, which had to be solved without any help in the remaining 30 minutes. This second part is considered as a post-test assessment of learning performance (section 3.2.5).

3.2.5 Learning performance

Both post-tests for history consisted of five multiple-choice questions (facts and dates) and six essay questions (text comprehension). A total score was calculated and used as a measure of learning performance in history (Cronbach's alpha was .58, 1st year and .51, 2nd year).

For math, post-tests with five (1st year) and six (2nd year) math word problems were administered (Cronbach's alpha = .58, 1st year and .69, 2nd year). A total score was calculated and used as a measure of learning performance in math. In both years, the post-test items were parallel to the items in the learning tasks, that is, the surface structure of the post-test items differed from the one of the learning-task items, but the deep structure was the same.

3.3 Results

3.3.1 Development of metacognitive and intellectual abilities

MANOVAs were performed on the intellectual ability and metacognition scores with age as a within factor. The multivariate within-subjects effect on the intellectual ability scores was [$F(4,24) = 11.74$, $p < .001$, $\eta^2 = .66$]. 14-year-olds had a higher intelligence score than 13-year-olds. Anova on the quality of metacognitive skillfulness also revealed a significant age effect [$F(8,20) = 6.77$, $p < .001$, $\eta^2 = .73$]. The same tests were performed on the quantitative scores of metacognitive skillfulness. Again a significant age effect was found [$F(8,20) = 5.28$, $p < .001$, $\eta^2 = .68$][6]. 14-year-olds exhibited more and better metacognitive activities than 13-year-olds.

Separate univariate tests on the metacognitive and intellectual ability data show which subscale scores increased significantly between the first and the second year (Table 3.2). No effect was found for gender and/or ethnic background.

Table 3.2 Tests of Within-Subjects Contrasts (13 vs. 14 yrs.)

	F	Sig.
Verbal analogies	22.96	.000
Unfolding figures	16.21	.000
Memory	6.45	.017
MetaqlMathP	7.56	.011
MetaqlHistEv	9.71	.004
MetaqnMathO	25.86	.000
MetaqnMathP	14.18	.001
MetaqnMathEv	8.32	.008
MetaqnMathEl	22.38	.000
MetaqnMathTot	32.00	.000
MetaqnHistEv	9.15	.005

Note: MetaqlMathP means the score on the quality of planning activities for math; MetaqlHistEv means the score on the quality of evaluation activities for history; MetaqnMathO means the score on the quantity of orientation activities for math; MetaqnMathP means the score on the quantity of planning activities for math; MetaqnMathEv means the score on the quantity of evaluation activities for math; MetaqnMathEl means the score on the quantity of elaboration activities for math; MetaqnMathTot means the total score on the quantity of metacognition for math; MetaqnHistEv means the score on the quantity of evaluation activities for history.

3.3.2 The monotonic development hypothesis

To determine whether developmental processes affect the relation between intellectual ability (IA) and metacognition (Meta) as predictors of learning performance (LP), the results of both years were compared (Table 3.3).

[6] Because the quantitative metacognitive scores were positively skewed, loglinear and square root transformations on the data were performed. This did not alter the results.

Table 3.3 Correlations and semi-partial correlations

	IA	Meta	Semi-PartIA	Semi-PartMeta
Quality				
LP Math13	.79**	.74**	.39*	.33*
Meta Math13	.65**			
LP Math14	.57**	.74**	.22	.52**
Meta Math14	.51**			
LP History13	.42*	.66**	.23	.53**
Meta Hist13	.27			
LP History14	.25	.36	.17	.33*
Meta Hist14	.32			
Quantity				
LP Math13		.76**	.37*	.30*
Meta Math13	.69**			
LP Math14		.42*	.47**	.28*
Meta Math14	.27			
LP History13		.57**	.31*	.50**
Meta Hist13	.20			
LP History14		.24	.24	.22
Meta Hist14	.21			

Note: LP means Learning performance * $p < .05$, ** $p < .01$

As far as the math task concerned intellectual ability correlated significantly with both the quality of metacognitive skillfulness and the learning measure in both years. The same applies for the correlation between the quality and the quantity of metacognitive skillfulness on the one hand, and the learning performance for math on the other. Intellectual ability and the quantity of metacognition in math correlated significantly among 13-year-olds only. The results on the history task differ partly from the results on the math task. Only in the first year a significant correlation was found between intellectual ability and the learning performance. The same applies for the correlation between the quantity of metacognitive skillfulness and the learning performance. The correlation between the metacognitive quality and the learning performance was significant in both years.

In order to test the mixed model the semi-partial correlations (Nunnally, 1967) were calculated (Table 3.3) by partialling Metacognitive skillfulness from the correlation between Intellectual ability and the Learning performance (i.e., semi-partIA) and partialling Intellectual ability from the correlation between Metacognitive skillfulness and the Learning performance (i.e., semi-partMeta). Next, the unique, independent contribution of Metacognitive skillfulness and Intellectual ability to the Learning performance was calculated. Using regression-analytic techniques (Pedhazur, 1982; Veenman & Spaans, 2005) the unique and shared proportions of variance in the learning performance were distributed to metacognitive skillfulness and intellectual ability (Table 3.4).

Table 3.4 Percentage of variance accounted for in Learning performance

	Intel unique		Meta unique		Shared		Total	
	QL	QN	QL	QN	QL	QN	QL	QN
History 13	5.2	9.7	28.0	24.6	10.8	7.9	44.0	42.2
History 14	2.9	5.5	11.3	5.0	5.3	1.0	19.5	11.3
Math 13	15.2	13.5	10.9	8.8	41.0	48.9	67.1	71.2
Math 14	5.1	22.2	27.3	7.9	27.2	10.1	59.6	40.2

Note: Intel unique means the unique contribution of Intellectual ability to Learning performance; Meta unique means the unique contribution of Metacognitive skillfulness to Learning performance; Shared means the shared contribution of Intellectual ability and Metacognitive skillfulness to Learning performance. Total means the total contribution of Intellectual ability and Metacognitive skillfulness to Learning performance. QL = qualitative metacognition scores; QN = quantitative metacognition scores.

Results in Table 3.4 show that, despite the variance shared with Intellectual ability, both qualitative and quantitative Metacognitive skillfulness, added to the prediction of Learning performance on top of Intellectual ability.

3.3.3 Metacognitive skillfulness across domains

The generality vs. domain specificity of metacognitive skillfulness was investigated by performing a principal component analysis (PCA) on the metacognitive scores. For each year separately, a PCA with a two-factor solution was performed on the four subscales of metacognitive skillfulness (Table 3.5).

Table 3.5 Unrotated component matrix for the quality of metacognitive skillfulness

	Component 1 13 yrs	Component 2 13 yrs	Component 1 14 yrs	Component 2 14 yrs
Eigenvalue	3.53	1.78	3.28	1.40
Variance proportion	.44	.22	.41	.17
MetaorientationHis	.50	.49	.51	-.45
MetaplanningHis	.72	.48	.49	-.46
MetaevaluationHis	.48	.52	.77	-.42
MetaelaborationHis	.72	.37	.89	-.14
MetaorientationMath	.61	-.57	.40	.23
MetaplanningMath	.78	-.31	.58	.61
MetaevaluationMath	.55	-.67	.69	.13
MetaelaborationMath	.86	-.16	.63	.59

The unrotated solutions of the PCAs show that all measures of the quality of metacognitive skillfulness substantially load on the first component (Table 3.5). Although not all component loadings are extremely high, these first components may be interpreted as representing general metacognitive skills across the two domains. On the other hand, we found contrasted loadings on both second components. This points in the direction of a component representing domain-specific metacognitive skills. The same analyses were performed on the quantitative scores. These results were in line with the results of the qualitative data.

3.4 Discussion

This study investigated the development of metacognitive skillfulness. Results show an overall growth of the quantity and quality of metacognitive skillfulness indeed. Looking closer into the subscales, we see an increase in the quality of planning in math. This means that 14-year-olds performed more and better planning activities. For history, the frequency of evaluating increased significantly. 14-year-olds not only evaluated more, they also evaluated on a higher level. This means that 14-year-olds not only monitored their own text comprehension more frequently than 13-year-olds, but they also did so on a higher, more effective level. In conclusion, the first hypothesis was confirmed.

From an instructional point of view, it would be interesting to know more about the sequence in which metacognitive skills develop over an extended period of time (Veenman, Van Hout-Wolters, & Afflerbach, 2006).

The second hypothesis concerned the relation between metacognitive skillfulness and intellectual ability as predictors of learning performance over age groups. Results were in line with the mixed model, similar to results of older students in earlier studies (Veenman & Beishuizen, 2004; Veenman & Verheij, 2003; Veenman et al., 2004). The unique contribution of Metacognitive skillfulness outweighed the unique contribution of Intellectual ability to Learning performance in history in both years. The math results show a changing role of Intellectual ability over the years: In the first year the unique contribution of Intellectual ability outweighed the unique contribution of Metacognitive skillfulness to Learning performance. In the second year, on the other hand, the results are developing in line with the history results. This difference in contribution of intellectual ability could be explained by a difference in the novelty of tasks, as experienced by participants. Compared to solving math word problems, the history task may have been less familiar to them, i.e., less in line with their usual schoolwork. In everyday school life students are not used to read lengthy history texts as used in this study. Moreover, they also were unfamiliar with the topic. Solving math problems was a more familiar task format to them. A high task novelty suppresses the impact of intellectual ability on learning performance (Elshout, 1987; Raaheim, 1988; Prins et al., 2006, Veenman & Elshout , 1999; Veenman, Prins, & Elshout, 2002).

We found a parallel development of metacognitive skillfulness and intellectual ability as predictors of learning performance in line with the monotonic development hypothesis. Earlier, Alexander et al. (1995) found that the developmental pattern was not consistent over different constituents of metacognition. They obtained evidence in favor of a monotonic development of metacognitive knowledge, but their results were inconclusive regarding metacognitive skills. Our results point in the direction of a monotonic development in metacognitive *skills* as well: A continuous growth of metacognitive skills with age, alongside intellectual growth (Veenman et al., 2004), thus corroborating hypothesis 2.

The third research question concerned the generality vs. domain specificity of metacognitive skillfulness. In both years, the solutions of the PCAs are very similar : A first component, which can be interpreted as general metacognitive skills, and a second component, which can be interpreted as domain-specific metacognitive skills. Results support our expectation that metacognitive skills of rather young and inexperienced students represent a general as well as a domain-specific component. Veenman and

Spaans (2005) assumed that metacognitive skills initially develop on separate islands of tasks and domains. Beyond the age of 12 years, these skills will merge into a more general repertoire that is applicable and transferable across tasks and domains. Among young students a phase of transition could be characterized by applying recently acquired general metacognitive skills, along with a remainder of domain-specific metacognitive skills. We expected that the initially acquired domain-specific metacognitive skills would tend to generalize during development. The present results, however, do not support this part of hypothesis 3 as yet. Next to drawing on a repertoire of general metacognitive skills students seem to continue applying domain-specific metacognitive skills as well. This may indicate that these students are still in a transitory phase of metacognitive-skill development. Being so, the general component would gain weight in the forthcoming years of development. On the other hand, it may indicate that metacognitive skills are only partly general by nature.

Despite finding significant results, there might be some limitations of the study. The small sample may be considered as a limitation to the generalizability. The time-consuming method of protocol analysis of individual sessions did not allow for larger samples. About 220 hours a year were spent on the individual sessions, transcribing protocols, analyzing protocols and tests. The fact that all participants came from the same school might be a limitation too. The same applies for the dissimilarity in tasks. In order to measure the learning performance after studying a *new* task, it was not possible to administer the same tasks over the years. By piloting the tasks and consulting teachers we tried to make the relative difficulty level of the tasks for each year as comparable as possible. Furthermore, the period covering the development of metacognitve skills was rather short.

This study shows that metacognitive skills cannot be ignored as an important predictor of learning performance. These skills develop during an important phase in education. It would be interesting to replicate (parts of) this study over a longer period of time with more participants coming from various schools. Such an extended study could contribute to a better understanding of the development of particular metacognitive skills, and of how appropriate skills can be taught at the right time.