Chapter 17

Metacognitive Knowledge in Secondary School Students: Assessment, Structure, and Developmental Change

Wolfgang Schneider, Klaus Lingel, Cordula Artelt, and Nora Neuenhaus

Abstract The construct of metacognitive knowledge—that is knowledge on cognitive processes, was established as a determinant of cognitive development in the 1970s. Early research focused on the domain of memory development in pre- and primary school children. While research activities on metacognition have diversified over time, some core issues in the assessment, structure, and development of metacognitive knowledge still remain unresolved:

(1) How can metacognitive knowledge be assessed? (2) How does metacognitive knowledge develop in secondary school? (3) Is metacognitive knowledge domain-specific or domain-general? (4) To what extent are developmental changes in metacognitive knowledge and achievement interrelated?

We addressed these research questions within our longitudinal research project on the development of knowledge components. Our database included 928 German students who were tested on six measurement points (from Grades 5 to 9). The focus of the longitudinal study was on the assessment of metacognitive knowledge, as well as achievement in mathematics, reading comprehension, English as a foreign language, and the changes in these variables over time. In this chapter, the main results on these four research questions are presented, after a brief description of the historical research background. The results of the last assessment period are given special emphasis.

Keywords Metacognitive knowledge • Domain-specific knowledge • Longitudinal study • Reading skills • Mathematics • English as a foreign language

---

W. Schneider (✉) • K. Lingel
University of Würzburg, Würzburg, Germany
e-mail: schneider@psychologie.uni-wuerzburg.de; lingel@uni-wuerzburg.de

C. Artelt • N. Neuenhaus
University of Bamberg, Bamberg, Germany
e-mail: cordula.artelt@uni-bamberg.de; nora.neuenhaus@uni-bamberg.de

D. Leutner et al. (eds.), *Competence Assessment in Education*, Methodology of Educational Measurement and Assessment, DOI 10.1007/978-3-319-50030-0_17

17.1 Theoretical Background

Research on metacognitive development was initiated in the early 1970s by Ann Brown, John Flavell, and their colleagues (for reviews, see Brown et al. 1983; Flavell et al. 2002). At the very beginning, this research focused on knowledge about memory, which was coined "metamemory" by Flavell (1971). Later on, the concept was also applied to studies investigating children's comprehension, communication, and problem-solving skills (Flavell 2000; Schneider and Pressley 1997). The term "metacognition" has usually been defined broadly as "any knowledge or cognitive activity that takes as its object, or regulates, any aspect of any cognitive enterprise" (Flavell et al. 2002, p. 150). According to this conceptualization, metacognition refers to people's knowledge about their own information-processing skills, the nature of cognitive tasks, and strategies for coping with such tasks. Moreover, it also includes executive skills related to the monitoring and self-regulation of one's own cognitive activities.

Most recent models of metacognition differentiate between declarative and procedural components of metacognition. This basic distinction, already apparent in Flavell and Wellman's (1977) taxonomy of metamemory, seems widely accepted in the developmental and educational literature (cf. Alexander et al. 1995; Kuhn 2000; Schneider 2010; Veenman et al. 2006). Nonetheless, it has also been argued that these two aspects of metacognition complicate its definition (see Joyner and Kurtz-Costes 1997). That is to say, while the two components are closely related, they are also fundamentally different in nature. Whereas the declarative knowledge component is primarily verbalizable, stable, and late-developing, the procedural knowledge component is not necessarily verbalizable, is rather unstable, relatively age-independent, and dependent on the specific task or situation. Thus, although there are substantial relations between the procedural (actual regulation) and declarative aspects (knowledge base) of metacognition, both from an analytical point of view and on the basis of research findings on the development of these components, it seems worthwhile to distinguish between the two (see also Hacker et al. 2009; Schneider 2015; Schneider and Artelt 2010; Schraw and Moshman 1995).

In our research project, the focus was on the exploration of (declarative) metacognitive strategy knowledge. As to the differentiation between components of declarative metacognitive knowledge, Paris and Byrnes (1989, see also Brown 1978) distinguished between *declarative strategy knowledge* ("knowing that"), *procedural strategy knowledge* ("knowing how"), and *conditional strategy knowledge* ("knowing when"). All three knowledge components are necessary, in order to apply strategies effectively. Taking into account Borkowski's metamemory model (Borkowski et al. 1988), it also seems worthwhile to look at students' knowledge about the usefulness of a certain strategy in relation to other strategies: that is, their *relational strategy knowledge*. Relational strategy knowledge is particularly important when individuals have a repertoire of strategies at their disposal and have to decide which is most adequate. Aspects of conditional and relational strategy knowledge were considered to be central components of the metacognitive knowledge measure used in our research project, EWIKO (Entwicklung metakognitiven Wissens und bereichsspezifischen Vorwissens bei Schülern der Sekundarstufe: development of metacognitive knowledge and domain-specific knowledge in secondary school students; see details below).

There is general agreement that, in the early stages of knowledge acquisition, specific aspects of declarative and procedural metacognitive knowledge influence performance across tasks and settings, and that the likelihood of transfer from one setting to another is quite low. A wealth of evidence for the domain specificity of metacognitive acquisition processes has led to the conclusion that metacognitive skills must be taught in context (Jacobs and Paris 1987). Furthermore, it is believed that repeated application and practice of metacognitive strategies enables learners to apply these strategies in diverse settings and domains in later stages of development. Metacognition and self-regulated learning thus are often considered domain-general constructs that transfer or generalize across domains.

A question repeatedly discussed in the relevant literature concerns the extent to which metacognitive knowledge is domain-specific. That is, does it vary within the same person as a function of the domain under investigation, such as reading, mathematics, or foreign language learning? Is there empirical evidence that it tends to become more general—that is, comparable for the same person across different domains, with increasing age? The development of metacognitive knowledge has often been proposed to be context-dependent and domain-specific at an early stage, and assumed to generalize throughout elementary school (e.g., Schneider 2008).

Given that there is not much empirical evidence on this issue for secondary school students, this research question was of particular interest in the present study. It was assumed that students at the beginning of secondary school (fifth graders in the German school system) are at an early stage of generalizing domain knowledge in reading, mathematics, or foreign language learning, which makes it likely that metacognitive knowledge can be identified as domain-specific during this early period of secondary school. Given that metacognitive knowledge develops not only within particular subject domains but also during regular school-based activities such as homework, exam preparation, etc., we assumed that the impact of domain transcending general metacognitive knowledge should increase over time. The expectation was that interrelations among the three domain-specific knowledge components should increase over time, thus indicating the increasing importance of domain-general knowledge.

Another important issue is how to characterize the development of declarative metacognitive knowledge and its relationship to memory behavior and (academic) performance. On the one hand, the empirical evidence suggests that declarative metacognitive knowledge increases substantially over the elementary school years. From early adolescence on, it is relatively stable, in the sense that individual differences do not change much over time. On the other hand, the procedural component of metacognition seems more “situated” and thus more unstable, since the actual regulation of learning depends on the learners’ familiarity with the task, as well as on their motivation and emotions. Individuals need to regulate their thoughts about which strategy they are using and adjust its use to the situation in which it is being applied. Given that the selection and application of strategies during learning depends not only on metacognitive knowledge but also on individual goals, standards, situational affordances, text difficulty, task demands, and so forth (Campione and Armbruster 1985; see also Winne and Hadwin 1998), it cannot be assumed that strategies will be applied whenever possible. However, an individual who uses a particular strategy intelligently ought to have some metacognitive knowledge of that strategy. In other words, there is a correlation between metacognitive knowledge and the effective use of strategies, which should also affect memory performance. Although metacognitive knowledge is assumed to be a necessary condition, it may not be sufficient for reflective and strategic learning or for academic achievement, because other factors such as IQ, domain knowledge, and memory capacity (working memory) also play a role.

17.1.1 Methodological Issues Regarding the Assessment of Declarative Metacognitive Knowledge

Before we deal with these issues in more detail, we briefly discuss a methodological problem that has concerned developmental research on declarative metacognition for quite a while, and which has to be solved before substantive issues can be tackled in a meaningful way.

Most evidence for the impact of declarative metacognitive knowledge on learning and achievement is provided by studies using assessment procedures such as open interviews, or concurrent measures such as observation and think-aloud analysis (see Schneider and Pressley 1997, for a review). Standardized assessments (and especially paper-and-pencil instruments) that are also used to assess metacognition often fail to provide empirical evidence for a positive correlation between (metacognitive) learning strategies and achievement (Lind and Sandmann 2003; Muis et al. 2007). According to Artelt (2000), potential explanations for such low correlations can be described as follows: First, most of the classic inventories for assessing metacognition and strategy knowledge are constructed in such a manner that students have to judge the frequency of their strategy use (e.g., Pintrich et al. 1993; Schraw and Dennison 1994). Thus, these instruments draw primarily on students' recognition of strategies (i.e., their long-term memory) and not so much on their declarative metacognitive knowledge (Leopold and Leutner 2002). Second, such frequency judgments are not well suited for younger age groups, because they are cognitively demanding and require high degrees of abstract thinking, as well as the ability to objectively generalize over past behaviors—which in turn is likely to be influenced by social desirability and memory bias (Schraw 2000). Third, the instruments are incapable of assessing metacognitive knowledge independent of strategy usage. From a theoretical perspective this is problematic, because a potential gap between competence and performance might distort the metacognitive knowledge pupils possess when it is assessed through frequency judgments of strategy usage. Consequently, the quality of metacognitive knowledge remains subject to speculation.

To avoid such problems, more sophisticated measures of metacognition have to be used with older children and adolescents. Schlagmüller and Schneider (2007) came up with a standardized measure of metacognitive knowledge on reading that was based on a revised test instrument developed for PISA 2000 (see Artelt et al. 2001). The same approach, and some of the material, was later used as part of the international assessment in the PISA 2009 study (see Artelt et al. 2010). This instrument taps adolescents' knowledge of strategies that are relevant during reading and for comprehension, as well as for recall of text information. For each of up to six scenarios, students have to evaluate the quality and usefulness of five different strategies available for reaching the intended learning or memory goal. The rank order of strategies obtained for each scenario is then compared with an optimal rank order provided by experts in the field of text processing. The correspondence between the two rankings is expressed in a metacognition score, indicating the degree to which students are aware of the best ways to store and remember text information.

We decided to develop similar measures of metacognitive knowledge for our EWIKO study by asking students explicitly to judge the appropriateness and (relative to other strategies) the quality of specific strategies for a given learning situation (Artelt et al. 2009). Within the assessment of metacognitive knowledge, we thus concentrate on students' correct, veridical knowledge, implying that high scores on the knowledge measure do, in fact, indicate that an individual possesses adequate strategy knowledge.

17.1.2 Design of the EWIKO Study

Our initial sample consisted of 928 German fifth graders (450 female, 478 male) from 44 classrooms representing three different educational tracks (271 high, 377 intermediate, and 280 low)[1] who voluntarily participated in a class-wise administered paper-and-pencil assessment. There were six assessments during the course of the longitudinal study, starting at the beginning of Grade 5 and ending in Grade 9. The group-based tests took place in the classroom during schooling hours. At each measurement point, testing time took about three school lessons (45 min. each) replacing the regular class teaching for this period. During the 135 min test sessions, each participant filled in domain-specific metacognitive knowledge tests, the achievement tests, and additional scales assessing cognitive abilities and motivational variables (see below). All tests were administered by two research assistants specially trained to instruct the participants and to lead them through the session. The classroom teacher was also present to ensure discipline among students.

Fig. 17.1 gives an overview of the time schedule concerning the presentation of metacognitive knowledge and achievement tests

---

[1] It should be noted that the elementary school period in the German school system finishes at the end of Grade 4. From Grade 5 on, students are allocated to three educational tracks: high = academic, intermediate, and low = vocational, mainly based on achievement scores in primary school.

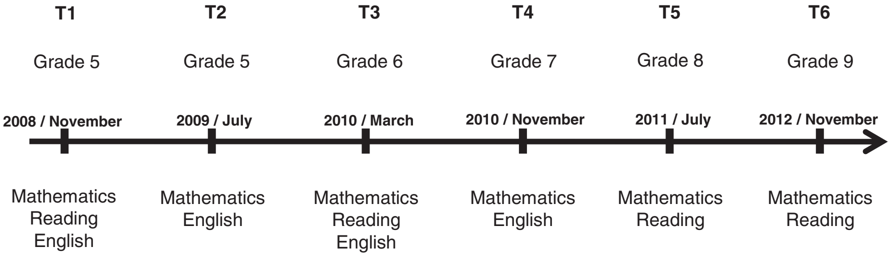

Fig. 17.1 Overview of the EWIKO design, showing how students were observed over a 4-year period between Grades 5 and 9 (time intervals between the adjacent measurement points being 8 months in Grades 5, 6, and 7, and 16 months in Grade 8 and 9, respectively)
T = Measurement point. Measurements included metacognitive knowledge and achievement in the corresponding domains

It should be noted that organizational problems caused us to expand the test intervals between T5 and T6. As expected, not all of the initial 928 students stayed with the longitudinal study. Missing data were generated for different reasons, for instance, due to student mobility (change of school), illness on the day of testing, and other reasons. Missing data rates varied between 38 % and 10 % (measurement points 6 and 2, respectively). Only 39 % of the students participated at all six measurement points. Post-hoc analyses revealed that the drop-out observed over the course of the project was systematic, indicating that more students with lower scores in achievement tests left the study (Lingel 2014; Lingel et al. 2014b). Thus, a missing pattern completely at random cannot be assumed (Little and Rubin 2002). To avoid biases in the results, we used regression-based strategies to impute the missing data (Neuenhaus 2011; Artelt et al. 2012; Lingel et al. 2014b).

17.1.3 Test Instruments

Assessment of Metacognitive Knowledge Due to organizational constraints, not all test instruments were applied at any given measurement occasion. Metacognitive knowledge in math was assessed at all six measurement points: that is, at intervals of about 8 months (T1–T5) and 16 months (T5–T6). Metacognitive knowledge in reading was assessed at intervals of 16 months from Grade 5 to Grade 9: that is, at T1, T3, T5, und T6. Metacognitive knowledge in English as a foreign language (EFL) was assessed at intervals of 8 months on four measurement occasions, from the beginning of Grade 5 until the beginning of Grade 7 (T1–T4).

The metacognitive knowledge tests were constructed to assess conditional and relational metacognitive knowledge in a situated way. The domain-specific tests were constructed to assess the metacognitive knowledge (MK) required for learning and achievement in the respective domains of mathematics, reading, and EFL (MK-mathematics; MK-reading; MK-EFL), in such a way that they provided

Scenario: “You have to understand and memorize a text. Give a grade to each of the following strategies. Better strategies should be given better grades. If you think that two or more strategies are of equal value, the same grades should be given to all of these strategies.”

		Grade					
		1	2	3	4	5	6
A	I concentrate on the parts of the text that are easy to understand.						
B	I quickly read through the text twice.						
C	After reading the text, I discuss its content with other people.						
D	I underline important parts of the text.						
E	I summarize the text in my own words.						

Fig. 17.2 Example of a metacognition scenario in the domain of reading
Note. The grade scale of the German school system used was 1 = *best grade*, 6 = *worst grade*

domain-typical learning situations in combination with a list of strategies of varying appropriateness (for a more detailed description of construction principles and examples of metacognitive tests tapping reading and mathematics see Artelt et al. 2010; Lingel et al. 2014b; Schlagmüller and Schneider 2007).

Scenario-based testing procedures were developed according to the principles used with the Index of Reading Awareness (“IRA”, Jacobs and Paris 1987).

In all tests, the students had to judge the relative effectiveness of strategies in a given situation (scenario) and in relation to other strategies. For an example concerning metacognitive knowledge related to reading, see Fig. 17.2. Scenarios in EFL concerned, among others, strategies related to vocabulary learning, and those for mathematics dealt, for example, with problem-solving activities in the context of a difficult math task (see also Artelt et al. 2009; Artelt and Schneider 2015).

Each test consisted of five tasks, beginning with a description of a typical learning scenario and followed by a list of efficient and less efficient strategies. Students had to judge the appropriateness of the strategies with respect to the scenario and in relation to the other strategies. An expert survey was conducted in all domains to ensure content validity of the tests and to provide an objective criterion for the efficiency of strategies (Neuenhaus 2011; Lingel 2014). In a pilot study, 311 students answered the test for reading, 361 students worked on the test for EFL, and 393 students worked on the metacognitive test concerning math. The main purpose was to evaluate the age appropriateness and reliability of the metacognitive knowledge tests (Lingel et al. 2010). Overall, the measures were found to be of sufficient reliability and validity, with reliability scores ranging from $\alpha = .69$ (MK-EFL, T1) to $\alpha = .85$ (MK-mathematics, T4 and T6) and a median $\alpha = .83$. The test assessing metacognitive knowledge in mathematics constructed for Grades 5 und 6 has been published recently (MAESTRA 5–6+; Mathematisches Strategiewissen für 5. und 6. Klassen; mathematical strategy knowledge for Grades 5 and 6; Lingel et al. 2014a). It should be noted that different test versions were used at different occasions, using anchor-procedures founded on Item Response Theory to establish common scales for the various tests (Embretson and Reise 2000; for more details see Lingel 2014).

The number of anchor items between tests on adjacent measurement occasions ranged between 69 and 100 %.

Achievement To assess achievement in the domains of mathematics, reading, and English as a foreign language (EFL), tests were developed in accordance with the current curricula for Grades 5–8, and were piloted to ensure appropriateness for the given sample. To assess reading comprehension, a multiple-choice reading test was used that was developed for the longitudinal assessments within the BiKS project (e.g., Pfost et al. 2013). The test comprised three different texts at each measurement occasion. The texts contained between 225 and 552 words each and were accompanied by 7–12 multiple-choice items. Within 20 min, 28 items were administered in Grade 5 (T1) and 30 items in Grade 9 (T6). To ensure measurement of change in reading achievement across time, the items on both measurement occasions were vertically scaled using a unidimensional Rasch model based on anchor items that were applied repeatedly (see Embretson and Reise 2000). The internal consistency of the reading test was $\alpha = .75$ in Grade 5. The corresponding scores for reading in Grade 9 averaged around $\alpha = .82$.

Achievement in EFL was assessed using a self-developed English version of a stumble-word speed test. The test consisted of 35 sentences. Each sentence builds one item in such a way that it contains a word that doesn't belong there. Under time restrictions, students were asked to correct as many sentences as possible. In Grade 5 (T1) they were given 3 min to cross out the stumble words in all 35 sentences. In Grade 7 (T4) they were given 2 min to cross out the stumble words. The amount of correct responses per minute was used as an indicator of achievement in this domain. The test reliability was $r_{tt} = .82$ in Grade 5 and $r_{tt} = .91$ in Grade 7.

Achievement in mathematics was assessed using tests that primarily covered students' competencies in arithmetic and algebra. Precautions were taken to ensure that the content areas were represented in the curricula of all educational tracks. The tests were successively adapted to the increasing achievement level of the sample. Moreover, items of subsequent tests were vertically scaled using Rasch modeling based on anchor items, to allow for measurement of change. Again, anchor-item linking founded on Item Response Theory was used to establish common scales for the various tests. The tests comprised 30–33 items and proved generally reliable and valid. The internal consistencies (alphas) were .83, .85, and .90 for Grades 5 (T1), 7 (T4), and 9 (T6), respectively.

In addition to the assessment of metacognitive knowledge and achievement in the three domains, several cognitive and non-cognitive variables were considered in the longitudinal study, with the goal of further explaining individual differences in developmental trends.

Cognitive Abilities The age-group appropriate subscales "verbal" and "non-verbal analogies" of the "Kognitiver Fähigkeitstest für 4. bis 12. Klassen (KFT 4–12+R)" (test of cognitive ability) developed by Heller and Perleth (2000) were chosen as indicators of general cognitive abilities. These measures of fluid intelligence were provided at the first measurement point. Moreover, a traditional memory span task (forward and backward) was presented to assess students' basic memory capacity.

Motivational Variables Students' self-concept in the domains of reading, mathematics, and EFL, as well as their interest in these domains, was assessed by using brief scales. Similarly, students' learning goal orientation, as well as their performance goal orientation, was assessed with a brief (4-item) scale.

Finally, to consider the impact of socio-economic status, parents' occupational status was also assessed.

17.2 Overview of Major Results

17.2.1 Development of Metacognitive Knowledge: Sources of Interindividual Differences

As noted above, several studies on various aspects of cognitive development also observed metacognitive knowledge development as a by-product (Schneider and Lockl 2008). However, studies with a focus on the development of metacognition and that used comprehensive approaches to explain interindividual differences in this development, and to explore their potential causes, are still very scarce.

Overall, the longitudinal EWIKO findings show a substantial growth in different kinds of metacognitive knowledge over the observed period (Neuenhaus 2011; Artelt et al. 2012; Lingel 2014). The respective means and standard deviations are given in Table 17.1. Growth rates observed within the first 24 months of secondary school (T1–T4) ranged between $d = 0.51$ (EFL) and $d = 0.72$ (mathematics; see Artelt et al. 2012; Lingel 2014). During the 16-month period between T1 and T3, metacognitive knowledge in the domain of reading increased substantially and with roughly comparable speed ($d = 0.37$). This development did not last long, however. In the last 16 months of the study (T5–T6), growth rates decreased in general, ranging between $d = 0.10$ (mathematics) and $d = 0.12$ (reading).

A well-known source of interindividual differences is school track. The allocation of students to school tracks creates differential learning environments, and is often found to result in differential developmental processes in cognitive characteristics (e.g., Becker et al. 2012). In fact, the differences in metacognitive knowledge observed among the three school tracks, both at the beginning and at the end of secondary school, were substantial (cf. Artelt et al. 2012; Lingel 2014; Lingel et al. 2010; Neuenhaus et al. 2013).

As indicated by the effect sizes for metacognitive knowledge in the domains of mathematics, reading, and EFL in Table 17.2, developmental changes differ as a function of school track and domain. That is, for the domain of mathematics, the differences between the high and intermediate tracks increased over time, whereas the differences between the intermediate and low tracks decreased. Overall, the findings thus indicate that developmental changes in the intermediate track were less pronounced than in the high and low tracks. For the domain of reading, however, the differences between the three tracks remained more or less constant over

Table 17.1 Means (*M*) and standard deviations (*SD*) of metacognitive knowledge in the overall sample and as a function of school track

		T1		T4		T6	
		M	*SD*	*M*	*SD*	*M*	*SD*
MK-mathematics	All	100.0	10.00	107.21	11.51	109.64	10.81
	High	103.95	9.58	112.69	11.46	115.16	11.65
	Interm.	100.96	954	107.14	10.44	109.03	9.06
	Low	94.89	8.80	101.99	10.41	105.11	9.70
MK-reading	All	100.00	10.00	n.a.	n.a.	105.99	12.60
	High	104.32	9.93	n.a.	n.a.	110.61	13.73
	Interm.	100.50	9.05	n.a.	n.a.	106.68	11.04
	Low	95.16	9.15	n.a.	n.a.	100.59	11.33
MK-EFL	All	100.00	10.00	105.13	11.84	n. a.	n. a.
	High	103.30	9.64	110.87	11.94	n. a.	n. a.
	Interm.	100.97	9.21	105.99	10.65	n. a.	n. a.
	Low	95.50	9.75	98.41	9.78	n. a.	n. a.

Table 17.2 Differences between school tracks as effect sizes (*d*) for measurement points 1, 4, and 6

	T1		T4		T6	
	High vs. interm.	Interm. vs. low	High vs. interm.	Interm. vs. low	High vs. interm.	Interm. vs. low
MK-mathematics	*d*=0.30	*d*=0.61	*d*=0.48	*d*=0.45	*d*=0.57	*d*=0.36
MK-reading	*d*=0.38	*d*=0.53	n.a.	n.a.	*d*=0.37	*d*=0.48
MK-EFL	*d*=0.23	*d*=0.55	*d*=0.41	*d*=0.64	n.a.	n.a.

T1 = Measurement Point 1; *T4* = Measurement Point 4; *T6* = Measurement Point 6; *MK* = metacognitive knowledge; *all* = whole sample; *high* = academic track; *interm.* = intermediate track; *low* = low track; *n.a.* = test not administered

time, thus indicating that developmental change rates in this domain are not associated with track or achievement level. In the domain of EFL, however, the differences between all three tracks increased in the observed period of time. Thus, the initial differences seemed to accumulate over time. It should be noted that the same instruments were used to assess developmental changes in English over time, whereas in the case of mathematics and reading, items of subsequent tests were vertically scaled using Rasch modeling based on anchor items, to allow for assessment of change (see above).

Somehow similar results were found for students' gender. At the beginning of the observational period (T1), only slight differences were found in favor of girls (d = 0.06 for the domains of mathematics and EFL; d = 0.17 for the reading domain). During the course of secondary school, these differences increased, regardless of domain (T4: d = 0.38 for the domain of EFL, d = 0.29 for the mathematics domain, and d = 0.50 for the domain of reading at T6). These findings indicate that girls acquire more metacognitive knowledge than boys during the first years of secondary school, particularly in language-related domains.

More fine-grained analyses for the domain of mathematics showed that the effects of tracking and gender persisted after controlling for cognitive characteristics such as intelligence, working memory capacity, and for motivational characteristics such as academic self-concept and interest, as well as for socio-economic background (Lingel 2014).

The EWIKO design also permitted an examination of the influence of student-level characteristics on metacognitive knowledge growth. Lingel (2014) used cognitive, motivational, and socio-economic characteristics to predict interindividual differences at the beginning of Grade 5 and in intraindividual changes over time. Among the cognitive variables, fluid intelligence predicted interindividual differences in metacognitive knowledge at the beginning and during the course of secondary school. Motivational characteristics such as interest and self-concept, however, did not influence intraindividual development in metacognitive knowledge. In contrast, students' socio-economic background showed a stable influence on the developmental pattern, in the sense that higher socio-economic status (SES) was related to a more positive developmental level.

An interesting and somewhat unexpected finding was that metacognitive knowledge development was found to be more pronounced for female students, regardless of domain. In reading, gender differences at the first measurement point were already significant (see Neuenhaus et al. 2016). In comparison, there were no initial differences between girls and boys for EFL, which may be due to the fact that EFL was a novel domain for all students. There were also no gender differences in initial metacognitive knowledge concerning mathematics (Lingel 2014). Interestingly, girls acquired metacognitive knowledge at a faster rate in all three domains of interest during the following measurement points. However, the gender differences identified for metacognitive knowledge were not always accompanied by corresponding differences in achievement. For instance, whereas girls in the EWIKO study in general outperformed boys in the domains of reading and EFL, showing significantly better performance on the achievement tests, a discrepancy was found in the domain of mathematics: Here, girls—as compared to boys—showed a higher level of metacognitive knowledge but performed more poorly on the mathematics achievement tests (cf. Lingel 2014).

17.2.2 Domain-Specificity—A Transitional Period of Metacognitive Development?

As noted above, metacognitive knowledge has often been proposed to be context-dependent and domain-specific during an early stage of development, whereas is it supposed to generalize throughout primary school. Such a transition was particularly proposed by the Good Strategy User model (Pressley et al. 1989) which assumes a task-specific acquisition of knowledge about a given strategy. The application of the strategy generates declarative knowledge on the properties of the strategy as well as on differences and similarities with other strategies. An inductive integration of task- and domain-specific strategy knowledge leads to a more and more generalized metacognitive knowledge. Accordingly, a successive domain-general structure of metacognitive knowledge should emerge.

To test the validity of this assumption, we compared the dimensional structure of metacognitive knowledge at the beginning of secondary school (T1) with the dimensional structure at the middle (T4) and also at the end of secondary school (T6). More specifically, two comparisons concerned the dimensional structure of metacognitive knowledge related to mathematics and reading (T1 and T6), whereas another comparison focused on metacognitive knowledge related to mathematics and EFL (T1 and T4). These analyses extend the research of Neuenhaus et al. (2011) which focused on the first measurement point (T1).

First, metacognitive knowledge on mathematics and reading was analyzed by comparing a unidimensional, domain-general structure with a two-dimensional, domain-specific structure at the beginning of Grade 5. Neuenhaus et al. (2011) found clear support for a domain-specific two-factor solution. A two-factor solution with two separate factors describing metacognitive knowledge for mathematics and reading, fitted the data better than a single-factor solution with a common factor (Δ BIC = 696). Both factors were moderately correlated ($r = .51$). Further analyses using the EWIKO data assessed at the end of secondary school (Grade 9, T6) showed a comparable factor solution. Again, the two factor-solution fitted the data better than the one-factor solution (Δ BIC = 585). Compared to the earlier findings, both factors showed a slightly increased correlation of $r = .58$. These findings seem to indicate that metacognitive knowledge in the domains of mathematics and reading may integrate into a more general knowledge structure as a function of time. However, the increase in correlations was not significant ($p = .08$).

Due to the specifics of the study design, it was impossible to carry out identical longitudinal analyses for all three domains (see Fig. 17.1). To validate the above finding in a second step, we included metacognitive knowledge in the domain of EFL in the analyses, and compared two models of metacognitive knowledge in the domains of mathematics and EFL as well as change in their dimensional structure between measurement points 1 and 4 (Neuenhaus et al. 2016). At the beginning of Grade 5 (T1), a two-dimensional model of metacognitive knowledge fitted the data better than a one-dimensional, domain-general model (Δ BIC = 399). Both resulting factors were substantially correlated ($r = .49$). Two years later, at Grade 7 (T4), the analyses again confirmed a two-dimensional structure (Δ BIC = 701). The slight decrease in intercorrelations between factors (.49 at T1 versus .45 at T4) did not prove to be significant. In any case, however, this finding does not support the assumption that metacognitive knowledge tends to be more general with increasing age.

One major conclusion from these findings is that metacognitive knowledge shows a clear-cut domain-specific structure even at the end of secondary school. Thus, the domain-specificity of metacognitive knowledge does not seem to be a short-term, transitional state restricted to the early school period.

17.2.3 Interrelations Between Metacognitive Knowledge and Achievement

One final issue concerned the question whether the relationship between metacognitive knowledge and achievement would change over time. To answer this question, synchronous correlations between the metacognitive knowledge components and achievement in the various domains were calculated. Overall, the correlational findings indicate increases over time: In mathematics, synchronous correlations between metacognitive knowledge and achievement increased from $r = .31$ (T1) to $r = .42$ (T6). The same pattern was observed in EFL and reading: correlations increased from $r = .22$ (T1) to $r = .29$ (T4) in EFL, and from $r = .29$ (T1) to $r = .39$ (T6) in reading.

Correlational analyses do not inform about cause-effect relationships. Lingel et al. (2014b) aimed at assessing the effects of metacognitive knowledge on subsequent performance, and proved a predictive effect of metacognitive knowledge on mathematics achievement. In this study, three common shortcomings of correlational studies dealing with knowledge-performance relationships were considered: (1) predictor and criterion were chronologically ordered, (2) prior knowledge, as the most prominent predictor of achievement was ruled out by being included in the prediction equation, and (3) confounding variables such as intelligence, motivation, and socio-economic status were controlled for. Under these restrictive conditions, metacognitive knowledge explained about 1 % of mathematics achievement change. That is, a rather small but still unique contribution of metacognitive knowledge to the development of achievement is documented. Although one may ask whether the comparably small contribution of metacognitive knowledge to the explanation of changes in mathematics development is practically important, one should note that estimates of unique contributions typically underestimate the true effect, and that metacognition still explained variance in achievement changes after the impact of several other important factors had been controlled.

The nature of the relation of metacognitive knowledge and achievement is conceived as bi-directional. Artelt et al. (2012) and Neuenhaus (2011) confirmed this theoretical assumption for reading, as well as for EFL. Using cross-lagged models, metacognitive knowledge (T1) predicted achievement in the respective domain (T3) substantially: $ß = .42$ for reading, $ß = .56$ for EFL. Moreover, metacognitive knowledge in both domains showed a moderate to low stability ($ß = .36$ for reading and $ß = .28$ for EFL). When controlling for these autoregressive effects, the cross-lagged effects of metacognitive knowledge on achievement remained significant ($ß = .13$ for reading and $ß = .17$ for EFL) as did the effects of achievement on metacognitive knowledge ($ß = .17$ for reading and $ß = .18$ for EFL). These findings support the assumption of a bi-directional developmental process.

17.3 Discussion

Taken together, the findings of the EWIKO study summarized above indicate that metacognitive knowledge develops substantially during the course of secondary school. The growth processes in mathematics and reading assessed between Grades 5 and 9 were found to be negatively accelerated, indicating that more metacognitive knowledge is acquired at the beginning of secondary school than thereafter. The initial level of metacognitive knowledge already varied as a function of school track, with students from the higher track showing higher levels of metacognitive knowledge. Whereas the overall developmental trend in observed metacognitive knowledge was similar across domains, the differences between the tracks seem to be domain-specific. That is, these differences seemed to be stable and invariant in the domain of reading, to increase in the domain of English as a foreign language, and to be inconsistent (i.e., partly growing and partly shrinking) in the domain of mathematics.

Our results indicate that most assumptions regarding the developmental and differential trajectories for educational track and gender were confirmed. Significant differences in metacognitive knowledge by the beginning of secondary education are likely to be due to individual difference variables such as domain knowledge, cognitive ability, and motivation, given that all students shared the same learning environment until then. With the allocation of students into three educational tracks by the beginning of Grade 5, differences in learning standards, class composition features, and instructional practices become increasingly important. Such differences seem to affect the development of metacognitive knowledge, regardless of domain.

Our findings regarding gender differences in metacognitive knowledge and achievement are generally interesting. Gender differences at the entrance level of secondary school were significant only for reading and not for the two other domains. The homogeneous base level of metacognitive knowledge in EFL may point to the importance of domain-specific experience for the development of metacognitive knowledge. As noted above, EFL is a novel domain for students at the beginning of Grade 5, while they are well familiar with the domain of reading, in which significant base-level advantages in metacognitive knowledge for girls were found. But how to explain the non-significant differences in entrance levels of metacognitive knowledge for the domain of mathematics? Given that boys outperformed girls on the achievement level, this finding points to a specific advantage of girls on the knowledge component that does not however materialize in performance. This assumption is also supported by the inspection of growth curves in metacognitive knowledge. Over time, girls developed significantly more metacognitive knowledge, regardless of the domain under consideration. Although the difference in metacognitive knowledge in favor of girls increased as a function of time, this pattern was not paralleled by achievement gains in mathematics. The findings for the domain of mathematics seem special, supporting the pattern of findings reported by Carr and Jessup (1997) for elementary school students. Clearly more research is needed to explain the gender-related metacognition-performance dissociation in the domain of mathematics.

Our study also contributes to the discussion about the domain-specificity of metacognitive knowledge. Throughout the developmental period under investigation, we found little evidence for the assumption of the increasingly general character of metacognitive knowledge (Pressley et al. 1989): metacognitive knowledge does not seem to generalize across domains, but it continues to show a strong domain-specific structure at the end of secondary school. Thus, the domain-specificity of metacognitive knowledge does not seem to be a short-term, transitional state restricted to the early school period. However, it needs to be kept in mind that we used assessments that focused on domain-typical strategies as indicators of knowledge in that domain, and that the test for a tendency towards the more general nature of these knowledge components was based only on tests of the dimensionality of these findings. There may however be knowledge components that do in fact transfer or generalize, but that are not yet tapped by our domain-specific assessments.

In sum, the findings of the EWIKO study replicate well-established findings in the literature, but also provide new insights, in that several domains were considered simultaneously. In accord with the existing literature, it could be shown that metacognitive knowledge is an important predictor of achievement in secondary school students. There was also evidence for a bi-directional relationship between metacognitive and cognitive development (Flavell and Wellman 1977). Here, the assumption is that the use of cognitive strategies improves the quality of metacognitive knowledge, and that improvement in metacognitive knowledge leads to a more sophisticated use of problem-solving strategies. Although the present research clearly indicates the importance of declarative (verbalizable) metacognitive knowledge for the development of performance in various domains, the design of the EWIKO study did not include aspects of procedural metacognitive knowledge: that is, the impact of monitoring and self-regulation skills that theoretically should facilitate this developmental process (Pressley et al. 1989). Thus, further research should focus on more fine-grained analyses exploring the interchange between declarative and procedural metacognitive knowledge in improving performance levels in different achievement domains.

Acknowledgments The preparation of this chapter was supported by grant SCHN 315/36 and AR 310/8 from the German Research Foundation (DFG) in the Priority Program "Competence Models for Assessing Individual Learning Outcomes and Evaluating Educational Processes" (SPP 1293).

References

Alexander, J. M., Carr, M., & Schwanenflugel, P. (1995). Development of metacognition in gifted children: Directions for future research. *Developmental Review, 15*, 1–37. doi:10.1006/drev.1995.1001.

Artelt, C. (2000). *Strategisches Lernen* [Strategic learning]. Münster: Waxmann.

Artelt, C., & Schneider, W. (2015). Cross-country generalizability of the role of metacognitive knowledge for students' strategy use and reading competence. *Teachers College Record, 117* (online publication).

Artelt, C., Schiefele, U., & Schneider, W. (2001). Predictors of reading literacy. *European Journal of Psychology of Education, 16*, 363–383. doi:10.1007/BF03173188.

Artelt, C., Beinicke, A., Schlagmüller, M., & Schneider, W. (2009). Diagnose von Strategiewissen beim Textverstehen [Diagnosis of strategy knowledge about text comprehension]. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie, 41*, 96–103.

Artelt, C., Naumann, J., & Schneider, W. (2010). Lesemotivation und Lernstrategien [Motivation for reading and learning strategies]. In E. Klieme, C. Artelt, J. Hartig, N. Jude, O. Köller, M. Prenzel, et al. (Eds.), *PISA 2009. Bilanz nach einem Jahrzehnt* (pp. 73–112). Münster: Waxmann.

Artelt, C., Neuenhaus, N., Lingel, K., & Schneider, W. (2012). Entwicklung und wechselseitige Effekte von metakognitiven und bereichsspezifischen Wissenskomponenten in der Sekundarstufe [Development of metacognitive and domain-specific knowledge and their mutual effects in secondary school]. *Psychologische Rundschau, 63*, 18–25. doi:10.1026/0033-3042/a000106.

Becker, M., Lüdtke, O., Trautwein, U., Köller, O., & Baumert, J. (2012). The differential effects of school tracking on psychometric intelligence: Do academic-track schools make students smarter? *Journal of Educational Psychology, 104*, 682–699. doi:10.1037/a0027608.

Borkowski, J. G., Milstead, M., & Hale, C. (1988). Components of children's metamemory: Implications for strategy generalization. In F. E. Weinert & M. Perlmutter (Eds.), *Memory development: Universal changes and individual differences* (pp. 73–100). Hillsdale: Erlbaum.

Brown, A. L. (1978). Knowing when, where and how to remember: A problem of metacognition. In R. Glaser (Ed.), *Advances in instructional psychology* (pp. 77–165). New York: Halsted.

Brown, A. L., Bransford, J. D., Ferrara, R. A., & Campione, J. C. (1983). Learning, remembering, and understanding. In J. H. Flavell & M. E. Markman (Eds.), *Handbook of child psychology, Vol. 3: Cognitive development* (pp. 77–166). New York: Wiley.

Campione, J. C., & Armbruster, B. B. (1985). Acquiring information from texts: An analysis of four approaches. Thinking and learning skills. In J. W. Segal, S. F. Chipman, & R. Glaser (Eds.), *Thinking and learning skills* (pp. 317–359). Hillsdale: Erlbaum.

Carr, M., & Jessup, D. L. (1997). Gender differences in first-grade mathematics strategy use: Social and metacognitive influences. *Journal of Educational Psychology, 89*, 318–328. doi:10.1037/0022-0663.89.2.318.

Embretson, S. E., & Reise, S. P. (2000). *Item response theory for psychologists*. New York: Psychology Press.

Flavell, J. H. (1971). First discussant's comments: What is memory development the development of? *Human Development, 14*, 272–278. doi:10.1159/000271221.

Flavell, J. H. (2000). Development of children's knowledge about the mental world. *International Journal of Behavioral Development, 24*, 15–23. doi:10.1080/016502500383421.

Flavell, J. H., & Wellman, H. M. (1977). Metamemory. In R. V. Kail & W. Hagen (Eds.), *Perspectives on the development of memory and cognition* (pp. 3–33). Hillsdale: Erlbaum.

Flavell, J. H., Miller, P. H., & Miller, S. A. (2002). *Cognitive development* (4th ed.). Upper Saddle River: Prentice Hall.

Hacker, D. J., Dunlosky, J., & Graesser, A. C. (2009). *Handbook of metacognition in education*. New York: Routledge.

Heller, K., & Perleth, C. (2000). *Kognitiver Fähigkeitstest für 4. bis 12. Klassen* [Cognitive ability test for Grades 4–12]*, Revision (KFT 4–12+R).* Göttingen: Beltz.

Jacobs, J. E., & Paris, S. G. (1987). Children's metacognition about reading: Issues in definition, measurement, and instruction. *Educational Psychologist, 22*, 255–278. doi:10.1207/s15326985ep2203&4_4.

Joyner, M., & Kurtz-Costes, B. E. (1997). Metamemory development. In N. Cowan (Ed.), *The development of memory in childhood* (pp. 275–300). Hove: Psychology Press.

Kuhn, D. (2000). The theory of mind, metacognition and reasoning: A life-span perspective. In P. Mitchell & K. J. Riggs (Eds.), *Children's reasoning and the mind* (pp. 301–326). Hove: Psychology Press.

Leopold, C., & Leutner, D. (2002). Der Einsatz von Lernstrategien in einer konkreten Lernsituation bei Schülern unterschiedlicher Jahrgangsstufen [The use of learning strategies in a specific learning situation by students of different grade levels]. *Zeitschrift für Pädagogik, Beiheft, 45*, 240–258.

Lind, G., & Sandmann, A. (2003). Lernstrategien und Domänenwissen [Learning strategies and knowledge about domains]. *Zeitschrift für Psychologie, 211*, 171–192. doi:10.1026//0044-3409.211.4.171.

Lingel, K. (2014). *Metakognitives Wissen Mathematik: Entwicklung und Zusammenhang mit der Mathematikleistung in der Sekundarstufe I.* [Metacognitive knowledge about mathematics: Its development and its relation to math performance in secondary school] (Doctoral dissertation, Julius-Maximilians-Universität Würzburg, Würzburg). Retrieved from https://opus.bibliothek.uni-wuerzburg.de/frontdoor/index/index/docId/7280. Accessed 13 Jan 2016.

Lingel, K., Neuenhaus, N., Artelt, C., & Schneider, W. (2010). Metakognitives Wissen in der Sekundarstufe: Konstruktion und Evaluation domänenspezifischer Messverfahren [Metacognitive knowledge in secondary school: On the construction and evaluation of domain-specific measurement instruments]. *Zeitschrift für Pädagogik, Beiheft, 56*, 228–238.

Lingel, K., Götz, L., Artelt, C., & Schneider, W. (2014a). *Mathematisches Strategiewissen für 5. und 6. Klassen* [Test of mathematics-related strategy knowledge for Grades 5 and 6; MAESTRA 5–6+]. Göttingen: Hogrefe.

Lingel, K., Neuenhaus, N., Artelt, C., & Schneider, W. (2014b). Der Einfluss des metakognitiven Wissens auf die Entwicklung der Mathematikleistung am Beginn der Sekundarstufe I [Effects of metacognitive knowledge on the development of math achievement at the beginning of secondary school]. *Journal für Mathematik-Didaktik, 35*, 49–77. doi:10.1007/s13138-013-0061-2.

Little, R. J. A., & Rubin, D. B. (2002). *Statistical analysis with missing data*. Hoboken: Wiley.

Muis, K. R., Winne, P. H., & Jamieson-Noel, D. (2007). Using a multitrait-multimethod analysis to examine conceptual similarities of three self-regulated learning inventories. *British Journal of Educational Psychology, 77*, 177–195. doi:10.1348/000709905X90876.

Neuenhaus, N. (2011). *Metakognition und Leistung: Eine Längsschnittuntersuchung in den Bereichen Lesen und Englisch bei Schülerinnen und Schülern der fünften und sechsten Jahrgangsstufe* [Metacognition and achievements: A longitudinal study assessing reading and English language development in fifth and sixth grade students] (Doctoral dissertation, Otto-Friedrich-Universität Bamberg, Bamberg, Germany. Retrieved from https://opus4.kobv.de/opus4-bamberg/files/327/DissNeuenhausseA2.pdf. Accessed 13 Jan 2016.

Neuenhaus, N., Artelt, C., Lingel, K., & Schneider, W. (2011). Fifth graders metacognitive knowledge: General or domain specific? *European Journal of Psychology of Education, 26*, 163–178. doi:10.1007/s10212-010-0040-7.

Neuenhaus, N., Artelt, C., & Schneider, W. (2016) *Lernstrategiewissen im Bereich Englisch: Entwicklung und erste Validierung eines Tests für Schülerinnen und Schüler der frühen Sekundarstufe* [Learning strategies in the subject of English: Development and first validation of a test for secondary school students]. *Diagnostica*. doi:10.1026/0012-1924/a000171.

Neuenhaus, N., Artelt, C., & Schneider, W. (2013, April). *The development of metacognitive knowledge among secondary-level students from Grade 5 to Grade 9: Do gender and educational track matter?* Paper presented at the annual meeting of AERA, San Francisco.

Paris, S. G., & Byrnes, J. P. (1989). The constructivist approach to self-regulation and learning in the classroom. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic achievement: Theory, research and practice* (pp. 169–200). New York: Springer.

Pfost, M., Artelt, C., & Weinert, S. (Eds.). (2013). *The development of reading literacy from early childhood to adolescence: Empirical findings from the Bamberg BiKS Longitudinal Studies*. Bamberg: University of Bamberg Press.

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and Psychological Measurement, 53*, 801–813. doi:10.1177/0013164493053003024.

Pressley, M., Borkowski, J. G., & Schneider, W. (1989). Good information processing: What it is and how education can promote it. *International Journal of Educational Research, 13*, 857–867. doi:10.1016/0883-0355(89)90069-4.

Schlagmüller, M., & Schneider, W. (2007). *WLST-12. Würzburger Lesestrategie Wissenstest für die Klassen 7 bis 12 [Würzburg reading strategy knowledge test for Grades 7–12]*. Göttingen: Hogrefe.

Schneider, W. (2008). The development of metacognitive knowledge in children and adolescents: Major trends and implications for education. *Mind, Brain, and Education, 2*, 114–121. doi:10.1111/j.1751-228X.2008.00041.x.

Schneider, W. (2010). Memory development in childhood and adolescence. In U. Goswami (Ed.), *The Blackwell handbook of cognitive development* (pp. 347–376). London: Blackwell.

Schneider, W. (2015). *Memory development from early childhood through emerging adulthood*. New York: Springer.

Schneider, W., & Artelt, C. (2010). Metacognition and mathematics education. *ZDM Mathematics Education, 42*, 149–161. doi:10.1007/s11858-010-0240-2.

Schneider, W., & Lockl, K. (2008). Procedural metacognition in children: Evidence for developmental trends. In J. Dunlosky & B. Bjork (Eds.), *A handbook of memory and metacognition* (pp. 391–409). Mahwah: Erlbaum.

Schneider, W., & Pressley, M. (1997). *Memory development between two and twenty*. Mahwah: Erlbaum.

Schraw, G. (2000). Assessing metacognition: Implications for the Buros Symposium. In G. Schraw & J. C. Impara (Eds.), *Issues in the measurement of metacognition* (pp. 297–322). Lincoln: Buros Institute of Mental Measurements.

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19*, 460–475. doi:10.1006/ceps.1994.1033.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review, 7*, 351–371. doi:10.1007/BF02212307.

Veenman, M. V. J., van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition and Learning, 1*, 3–14. doi:10.1007/s11409-006-6893-0.

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Mahwah: Erlbaum.