The Impact of Cross-curricular Competences and Prior Knowledge on Learning Outcomes

Nora Neuenhaus[1], Cordula Artelt[1] & Wolfgang Schneider[2]

[1] Bamberg University, Germany

[2] Würzburg University, Germany

Correspondence: Nora Neuenhaus, Department of Educational Research, Bamberg University, Markusplatz 3, 96045 Bamberg, Germany. Tel: 49-176-2016-0474. E-mail: nora.neuenhaus@uni-bamberg.de

Received: October 19, 2013 Accepted: November 18, 2013 Online Published: November 19, 2013

doi:10.5430/ijhe.v2n4p214 URL: http://dx.doi.org/10.5430/ijhe.v2n4p214

Preparation of this paper was supported by grants SCHN 315/36-1 and AR 301/8-1 from the German Research Foundation (DFG) as part of its Priority Research Program "Competence Models for Assessing Individual Learning Outcomes and Evaluating Educational Processes" (SPP 1293).

Abstract

This review begins by outlining the historical discussion about the relative importance of fostering cross-curricular competencies versus domain-specific prior knowledge as central goals of education. Metacognition and prior knowledge are then introduced as constructs representing these two goals; their development and effects on learning outcomes are described from a theoretical perspective. Empirical research on metacognition and expertise—and especially on mechanisms of acquisition—is then presented, illustrating commonalities between the two concepts and drawing attention to the need to take interactions between the two into account when analyzing their impact on learning outcomes. Most of the research discussed in the article draws on cross-sectional data. Systematic longitudinal research of combined effects in different subject domains is required to gain a better understanding of developmental mechanisms and stage-specific effects.

Keywords: Metacognition, Expertise, Cross-curricular competencies, Prior knowledge

1. Introduction

The relative importance of domain-specific knowledge acquisition as compared to cross-curricular competencies is a longstanding matter of debate in educational circles, especially in the German tradition. Whereas knowledge acquisition is a core element of "materiale Bildung" (material education), "formale Bildung" (formal education or "formal discipline") focuses on developing more general thinking skills. Advocates of "educational materialism" claim that all knowledge needed for later life should—as far as possible—be taught in schools. Advocates of "educational formalism" argue that education should concentrate on generic skills or on training the "mental muscle" that enables students to acquire knowledge on their own (e.g., Lehmensick, 1926; Wertheimer, 1945). In more recent educational psychology, these two positions have been mirrored in the debate about situated learning and cognition (Greeno, 1998; Lave & Wenger, 1991) versus cross-curricular competencies such as self-regulated learning (Schunk & Zimmerman, 2008) and metacognition (Dunlosky & Metcalfe, 2009). In the situated learning paradigm, learning and knowledge is seen as being welded to the situation in which it is acquired, with little scope for spontaneous transfer to other situations (Hatano & Greeno, 1999). By contrast, most researchers concerned with cross-curricular competencies, assume that generally strategies and metacognition can be transferred to other situations (cf. Artelt, Baumert, Julius-McElvany, & Peschar, 2003; Neuenhaus, Artelt, Lingel, & Schneider, 2011). Zimmerman (1989) describes self-regulated learners as follows: "Students can be described as self-regulated to the degree that they are metacognitively, motivationally, and behaviorally active participants in their own learning process" (p. 4). The metacognitive aspect of learning, in particular, is central to the definition of self-regulated learning (Azevedo, 2009; Efklides, 2001; Schunk & Zimmerman, 1998, 2008): self-regulated learning processes are characterized by the regulatory or procedural components of metacognition (e.g., planning, monitoring, and evaluating) in interaction with a person's ability to select, combine, and coordinate strategies during learning. (Note 1)

Theoretical models of skill development and transfer may help to elucidate the role of domain-transcending versus domain-specific skills and competencies—and, in particular, the role of general skill (i.e., metacognition, intelligence) versus domain-specific expertise (Carr & Taasoobshirazi, 2008). Transfer can be defined as the ability to extend what has been learned in one context to new contexts. According to one of the oldest models, E. L. Thorndike's theory of identical elements (1913; Thorndike & Woodworth, 1901), transfer from one task to the other is a function of the degree to which identical elements (on the level of perception as well as behavior) are present. That is, transfer takes place when the original task is similar to the transfer task. However, this focus on elements of tasks disregards learner characteristics, such as whether relevant principles were extrapolated, when attention was directed, motivation to perform, and existing knowledge and strategies. Singley's and Anderson's (1989) reformulation of the theory of identical elements takes such learner characteristics into account, thereby shifting the perspective from an associational to a cognitivistic one (De Corte, 1999). From the situated cognition point of view, however, the cognitive concept of transfer has limitations. For example, it fails to take account of socio-cultural constraints on learning (Hatano & Greeno, 1999).

For the purposes of this article, the debate on domain-specific knowledge acquisition versus learning to learn will be specified by reference to the concepts of domain-specific prior knowledge as understood in the expert–novice paradigm and metacognition as the core component of self-regulated learning. Although we introduce the concepts separately in the following sections, they are not independent of each other. Interactions and dependencies between the two are described in the section on interrelations during learning. Finally, we discuss implications for research.

2. Expertise and prior knowledge

"If I had to reduce all educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." (Ausubel, 1968, p. VI)

The term "prior knowledge" embraces different types of knowledge acquired in various domains: general world knowledge, domain-specific factual knowledge, conceptual knowledge, and metacognitive knowledge to name but a few (Dochy & Alexander, 1995; Schneider & Bjorklund, 2003). In line with comparative studies of expertise, we focus on the impact of domain-specific prior knowledge.

The role of domain-specific prior knowledge for learning has been investigated in both cognitive and educational psychology. There is little argument about its importance for memory performance (for reviews, see Bjorklund & Schneider, 1996; Schneider & Pressley, 1997) and skill acquisition (Ericsson & Lehmann, 1999).

Memory models based on the information processing approach, in particular, provide theoretical explanations for the impact of domain-specific prior knowledge on learning and achievement. Particularly production systems help to explain the development of expertise. One of the most widely recognized cognitive production systems was proposed in the context of ACT* theory (Anderson, 1983) and later ACT-R theory. In ACT* theory, declarative and procedural knowledge are viewed as two poles of a continuum (Anderson, 1993). Three types of memory structures are proposed. Declarative memory is modeled as a semantic network; procedural memory contains production rules; working memory serves as an interface to the world outside. An automating process based on practice incrementally transforms declarative knowledge to procedural knowledge in three developmental steps (Anderson, 1982). First, declarative knowledge is encoded (declarative phase). Second, it is transformed to procedural knowledge (compilation phase). Third, procedural learning takes place through generalization (tuning phase).

Whereas declarative knowledge is thought to be explicit, procedural knowledge is assumed to be implicit. The acquisition of declarative knowledge is basically an accumulation of factual input. The acquisition of procedural knowledge requires more effort, but is also more beneficial. Once acquired, procedural knowledge can be applied with little effort. The application of declarative knowledge, in contrast, is resource consuming because it requires working memory capacity.

Network theory offers a framework describing the role of prior knowledge in the integration of new knowledge into declarative knowledge structures; it also accounts for the categorization of knowledge (e.g., Collins & Quillian, 1969). According to the semantic networks perspective, knowledge is stored in memory through concepts or notes that are interconnected via associations. If prior knowledge is available, new information can be mapped onto the existing knowledge representation, and the new concepts become connected to the existing ones via associations. The building of new associations and strengthening of existing associations are accomplished through simultaneous activation of two or more concepts at a time. The activation of concepts and the spread of this activation through the semantic network thus lead to the restructuring of knowledge. As activated concepts and associations become reinforced, associations between other concepts fade. Individuals with extensive prior knowledge in a particular domain possess highly salient concepts for the mapping of new information. If no prior knowledge is available, capacity-consuming structure-building processes are required to build a new conceptual foundation before new associations can be made (Gernsbacher, 1990).

Studies in the field of expertise research provided early evidence for the role of domain-specific prior knowledge in exceptional performance. The "wunderkind" research of the 1920s can be seen as the starting point for the investigation of expertise, exceptional performance, and its development. A very well received study often referred to as the pioneering study in the field, was presented by De Groot in 1946. A chess master himself, De Groot investigated the memory capabilities of chess masters as compared to novices. Drawing on think-aloud protocols, he aimed to identify the differences in the thought processes of the two groups, but failed. However, he found striking differences in memory for chess positions. Experts were able to correctly recall significantly more moves in a chess game than novices (De Groot, 1966).

Contrary to the assumption that innate ability is the main predictor of performance, the expert approach proposes a continuum from novice to expert, in which expertise can be reached through the accumulation of domain-specific knowledge and experience. In memory studies, novices were successfully trained to memorize extraordinary numbers of digits (Ericsson & Chase, 1982). Further evidence for the trainability of expert performance was provided by studies on experts in various domains, such as chess, medicine, music, and sports. The acquisition of expertise is seen as an effortful and long-term process requiring at least 10 years of extensive practice (Ericsson & Lehmann, 1996). Consequentially, expertise is highly domain specific (Gobet & Simon, 1996) and does not transfer to other domains.

In a very broad sense, expertise can be defined as continued exceptional performance in a particular domain. Chess masters, famous musicians, and ballet dancers are easily categorized as experts by this definition: the difference between experts and novices is so great that it is easy to observe and identify expert–novice differences. For professionals or school students, however, such an absolutistic definition seems insufficient: in fields where many people reach relatively high levels of performance, the distinction between experts and novices is usually not very clear. For this reason, studies in educational and cognitive psychology usually rely on a relativistic definition of expertise. Respondents are assigned to the group of experts or novices by median split or because they fall into an operationally defined subset based on their score on a chosen indicator (achievement or performance measures).

There is broad consensus that experts possess a richer knowledge base than novices. Both the quantity and the quality of their domain-specific prior knowledge is superior in that it is more elaborate and better organized (Chi, Glaser & Reese, 1982). According to ACT theory, expertise is mediated by knowledge, in that knowledge must first be acquired before it can be transferred to the productions and skilled actions necessary to reach an expert level of performance (Ericson and Lehmann, 1999). Experts develop automaticity and their knowledge becomes procedural (Anderson, 1982). This automaticity frees up working memory resources for more complex task demands or self-regulation. Bransford, Brown, and Cocking (2000) describe differences between experts and novices in terms of key principles of experts' knowledge. The principles they identify include the following (p. 31):

(1) Experts have acquired a great deal of domain-specific knowledge which is organized in ways that reflect a deep understanding of their subject matter.

(2) Experts' knowledge cannot be reduced to sets of isolated facts or propositions; rather, it reflects contexts of applicability: that is, expert knowledge is "conditionalized" on a set of circumstances.

(3) Experts are able to flexibly retrieve important aspects of their knowledge with little attentional effort

(4) Experts have varying levels of flexibility in their approach to new situations

Research taking a closer look at experts' organization of and access to knowledge has shown that experts organize their knowledge efficiently (Schneider, 2010). Meaningful relations among elements are clustered into related units that are governed by underlying concepts and principles, sometimes described as big ideas. According to Bransford et al. (2000) "knowing more" in this context means having more conceptual chunks in memory, more relations or features defining each chunk, more interrelations among the chunks, and more efficient methods for retrieving related chunks and procedures for applying these information units in problem-solving contexts (Chi, Glaser, & Rees, 1982). Experts' ability to retrieve knowledge quickly is sometimes attributed to the fact that their knowledge is "conditionalized," meaning that it includes a specification of the contexts in which it is useful (Glaser, 1992), allowing "relatively effortless" (fluent) or even "automatic" retrieval of relevant knowledge (Schneider & Shiffrin, 1977).

Another key characteristic of experts seems to be their engagement in metacognitive processes such as evaluation, monitoring, and regulation (Glaser, 1985). Expert performance is characterized by high flexibility and swift adaptation to situational demands. This may be due in part to their frequent application of domain-specific strategies, which develop with increasing expertise (Veenman & Elshout, 1999). Experts are usually more concerned with improving processes of leaning than with improving learning outcomes (Kitsantas & Zimmerman, 2002). To this end, they develop metacognitive competencies (monitoring, regulation) and engage in self-regulatory behavior (Zimmerman, 2006). It is this engagement in self-regulatory processes combined with the motivation to optimize the processes necessary for high levels of performance that is often described as distinguishing experts from novices, because mechanisms of self-regulation, metacognitive engagement, and motivation interact in the development of expertise.

3. Metacognition

For decades, metacognition has been a subject of considerable attention in research on cognitive and developmental psychology (Schneider, 2008). Although there has been criticism that the definition of the concept is imprecise, its relevance for research and practice in educational psychology is widely recognized. Metacognition research emerged in the early 1970s, when the concept of metamemory was incorporated in models of memory development (for reviews, see Brown, Bransford, Ferrara, & Campione, 1983; Flavell, Miller, & Miller, 2002; Schneider & Pressley, 1997). Flavell's (1971) conception of metamemory was global, encompassing knowledge of all possible aspects of information storage and retrieval. Accordingly, metamemory included (but was not limited to) knowledge about memory functioning, difficulties, and strategies. Flavell and Wellman (1977) distinguished two main categories of metamemory: "sensitivity" and "variables." The "sensitivity" category referred to mostly implicit, unconscious behavioral knowledge of when memory is necessary, and thus was very close to subsequent definitions of procedural metacognitive knowledge. The "variables" category referred to explicit, conscious, and factual knowledge about the importance of person, task, and strategy variables for memory performance. This is also known as declarative metacognitive knowledge. Flavell and Wellman conceived of these categories and subcategories as overlapping and interactive. Brown's (1978; Brown et al., 1983) reconceptualization of metamemory focused on procedural metamemory ("here and now memory monitoring") and children's text processing.

In a seminal paper, Flavell (1979) argued that metamemory was not isolated from knowledge about other aspects of the mind, and he generalized the metamemory taxonomy developed in Flavell and Wellman (1977) to metacognition in general. Although various definitions of the term "metacognition" have been used in the literature on cognitive development, the concept has usually been broadly and rather loosely defined as any knowledge or cognitive activity that takes as its object, or regulates, any aspect of any cognitive enterprise (Flavell et al., 2002). Obviously, this conceptualization refers to people's knowledge of their own information processing skills, as well as knowledge about the nature of cognitive tasks, and about strategies for coping with such tasks. Moreover, it includes executive skills related to the monitoring and self-regulation of one's own cognitive activities. Flavell (1979) described three major facets of metacognition, namely metacognitive knowledge, metacognitive experiences, and metacognitive skills (i.e., strategies controlling cognition). According to Flavell et al. (2002), declarative metacognitive knowledge refers to the segment of world knowledge that has to do with the human mind and its doings. Metacognitive experiences refer to a person's awareness and feelings elicited in a problem solving situation (e.g., feelings of knowing), and metacognitive skills are believed to play a role in many types of cognitive activity, such as oral communication of information, reading comprehension, attention, and memory.

The taxonomy of metamemory presented by Flavell and Wellman (1977) was not intended to be exhaustive. Since the late 1970s, a number of additions and changes have been suggested (for reviews, see Holland Joyner & Kurtz-Costes, 1997; Schneider, 1999; Schneider & Pressley, 1997). For instance, Paris and Oka (1986) introduced a component labeled conditional metacognitive knowledge that focused on children's ability to justify or explain their decisions concerning memory activities. Whereas the declarative metamemory component first introduced by Flavell and Wellman (1977) focused on "knowing that," conditional metamemory referred to "knowing why." The procedural metamemory component emphasized by Brown and colleagues, that is, children's ability to monitor and self-regulate their memory-related behavior, refers to "knowing how" and plays a major role in complex cognitive tasks such as comprehending and memorizing text materials. Overall, the distinction between declarative and procedural metacognitive knowledge is widely accepted in developmental and educational psychology. Although these components are generally conceived of as relatively independent, empirical findings suggest that they can mutually influence each other (Schneider, Körkel, & Weinert, 1987; Schraw, 1994). For instance, a student who knows that she is prone to make careless errors may increase her self-regulatory activities in test situations.

Although various studies indicate that older and higher-achieving students show superior metacognitive knowledge and regulation (e.g., Baker & Brown, 1984; Hacker, 1998), the very broad definition of metacognition makes it difficult to describe a general developmental trajectory. Disparate developmental pathways can be identified depending on the research focus and the working definition of the construct investigated. In order to integrate these empirical findings, it is necessary to consider the conceptualization of metacognition and to describe the developmental trajectories accordingly.

An important distinction in this regard is that between declarative and procedural metacognition. As described above, declarative metacognition involves knowledge of person-, task-, and strategy variables and the interaction of this knowledge regarding when and how to engage in particular cognitive processes (strategies). Because this knowledge is assumed to be accessible to conscious processing, assessments of declarative metacognition often rely on verbal reports, interviews, knowledge tests, or questionnaires (see Schraw & Impara, 2000). Procedural metacognition entails the actual regulation of the learning process (e.g., the deployment of strategies) and thus consists of knowledge on how to perform in certain situations. It is often described as an executive control component (Borkowski & Kurtz, 1987) that enables individuals to monitor, control, and evaluate their cognitive activities (Baker & Brown, 1984). However, the precise nature of procedural metacognitive knowledge has been a controversial topic of discussion. In line with the procedural knowledge component of ACT* theory, it can be viewed as automated and primarily implicit knowledge (Ehrlich, Remond, & Tardieu, 1999; Samuels, Edinger, Willcutt, & Palumbo, 2005). Studies applying think-aloud techniques or interviews to investigate procedural metacognition implicitly assume that it is to some degree accessible to conscious processing and can thus be verbally expressed. Other measurement approaches use indirect measures, such as the analysis of log files or other traces of learning (see Schraw & Impara, 2000).

Procedural knowledge is assumed to develop rather early in life. Studies based on self-judgments have shown that preschool children are already able to evaluate their knowledge and learning achievement on very simple and familiar tasks (Lockl & Schneider, 2007; Schneider & Lockl, 2008). Although metacognitive monitoring starts to develop in early childhood, research has found increases in the accuracy of judgments throughout the elementary school years, with a major improvement in metacognitive monitoring at the transition from preschool to primary school (Paris, Morrison, & Miller, 2006). An important reason to study metacognitive monitoring processes is because they are thought to play a key role in determining how people study. Numerous studies with adult participants have shown that individuals use memory monitoring, especially judgments of learning, to control their learning. Based on the results of this monitoring process, they decide which content to focus on and for how long (e.g., Metcalfe, 2002; Nelson, Dunlosky, Graf, & Narens, 1994; Nelson & Narens, 1990; Son & Metcalfe, 2000). However, little is known about how children use monitoring to regulate their study time. Developmental studies on the allocation of study time examined whether schoolchildren and adults were more likely to spend more time on less well-learned material (e.g., Dufresne & Kobasigawa, 1989; Masur, McIntyre, & Flavell, 1973). All of these studies reported an age-related improvement in the efficient allocation of study time. That is, older children (from age 10 on) spent more time studying hard items than easy items, although many young children were already able to distinguish between hard and easy items. Thus, developmental differences were not observed as much in metacognitive knowledge itself as in its efficient application to self-regulation strategies. For a detailed discussion of the complex relationship between control and monitoring, see Schneider (in press).

Declarative metacognitive knowledge develops later than procedural metacognition. In a well received interview study, Kreutzer, Leonard and Flavell (1975) showed that declarative metacognitive knowledge continues to develop from first to fifth grade. Even though it is widely assumed that most strategy development takes place at the beginning of primary schooling, preschool children are known to already have some rudimentary strategy knowledge (Baker, 2005). Metacognitive knowledge on the contrary does not typically develop until children enter school (Schneider & Pressley, 1989), and it continues to develop throughout the school years (Artelt, Neuenhaus, Lingel, & Schneider, 2012) and into adulthood (Schneider & Lockl, 2008). Even in adulthood elaborated declarative metacognition cannot be taken for granted (Brown et al., 1983). It seems important to note that, although metacognitive knowledge increases substantially between early childhood and early adulthood, many adolescents (including college students) demonstrate little knowledge of powerful and important memory strategies that can facilitate the reading, comprehension, and memorization of complex text materials (cf. Brown et al., 1983; Pressley & Afflerbach, 1995).

However, major increases in metacognitive development are assumed to take place during the secondary years, meaning that there is great scope for instructional interventions in schools (Carroll, 2008). Having said that, most developmental studies conducted to date have concentrated on elementary school students. Almost all studies with middle school and high school students have been interventional. These studies testify to the potential for metacognitive development through specific training programs and instruction, but provide few insights into the regular development of metacognition in secondary school.

Several models describing the development of metacognition and the acquisition of metacognitive strategies have been proposed in the literature, providing general insights into the developmental trajectories of metacognition and strategic learning. It is commonly agreed that the most mature state is characterized by flexible adaptation to learning situations and successful performance on challenging and unfamiliar tasks. Accordingly, the availability of strategies, as well as their flexible and effective application, is crucial for the development of metacognitive knowledge and skills.

A deficit-oriented model of metacognitive development explains the lack of successful and effective strategy usage often found in early stages of development by reference to three deficit stages (Hasselhorn, 1996). At the first stage, young children are incapable of applying even those strategies that are explicitly taught (mediation deficit; Reese, 1962). The second stage is characterized by students' inability to spontaneously apply the strategies they know (production deficit; Flavell, 1970). Third, students need to overcome the inability to gain learning benefits by applying a strategy (utilization deficit; Miller, 1990). At this stage, strategies are used spontaneously but with high costs in terms of cognitive resources. Through practice, strategy application becomes routinized and thus more procedural. The final stage of strategic maturity is reached when learners apply strategies spontaneously and generalize their effective application across situations and tasks.

Pressley, Borkowski and colleagues have taken a broader perspective on the development of metacognition. The Good Strategy User model (Pressley, Borkowski, & Schneider, 1987, 1989) and the metamemory model (Borkowski, Milstead, & Hale, 1988), for example, propose a developmental trajectory in which metacognitive knowledge becomes increasingly differentiated and can be used more flexibly (see also Siegler, 2007). The central process of metacognitive development is the acquisition of strategies to develop a repertoire of generalized strategies. As a first step, specific strategies are learned. Through repeated application of a strategy, individuals become familiar with its attributes (e.g., effectiveness or appropriateness in certain situations). With time, this specific strategy knowledge increases. As the strategy repertoire grows, relational strategy knowledge develops to support the selection of task-appropriate strategies. Strategy generalization and the transfer of strategies are moderated by practical experience. As general strategy knowledge accumulates, individuals' motivations and beliefs come into play. Successful utilization of strategies can foster the development of positive self-efficacy beliefs as well as optimistic attribution styles for learning outcomes (Borkowski, Chan, & Muthukrishna, 2000). Thus, with increasing (learning) experience, strategic knowledge (conceived of as specific, relational, and general strategic knowledge) becomes gradually more differentiated. With increased knowledge about the value of strategy use, in particular, the use of learning strategies becomes more effective. In a parallel development, motivational components such as attribution style, self-concept, and self-efficacy beliefs undergo change. It can therefore be assumed that, with increasing age, students gain access to a more differentiated repertoire of strategies that can be put to effective use in a range of situations. Indeed, the learning of an expert learner is characterized by a rich repertoire of learning strategies that can be applied flexibly.

Other developmental approaches consider the role of social interactions and social models in conveying metacognitive processing and self-regulative behavior (e.g., Baker, 1996, Zimmermann, 2000). Drawing on Bandura's (1986) social learning theory, we can expect social models to play an essential role in the first two developmental stages of self-regulation: the phase of observation and the phase of emulation. At the third stage, learners are capable of executing strategies under structured conditions without the presence of a social model. They are in "self-control." The final stage of "self-regulation" is reached when individuals become increasingly able to use and adapt strategies flexibly in response to the changing demands of learning situations.

There is general agreement that, in the early stages of acquisition, metacognitive knowledge and control fluctuate across tasks and settings, and that the likelihood of transfer from one setting to another is quite low. A wealth of evidence for the task or domain specificity of metacognitive acquisition processes has led to the conclusion that metacognitive skills must be taught in context (Paris, Jacobs, & Cross, 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 are thus often considered domain-general constructs that transfer or generalize across domains. Nevertheless, some researchers maintain that even metacognition is domain specific. Baker and Cerro (2000), for example, draw attention to the lack of evidence for a general or domain-transcending metacognitive ability.

However, inspection of the recent literature on transfer shows that even modern models of transfer emphasize active and self-regulatory processes. Transfer is not a passive end-product of a particular set of learning activities, but requires learners to actively choose and evaluate strategies, consider resources, and receive feedback (Bransford et al., 2000). Transfer can be improved by helping students to become more aware of themselves as learners who actively monitor their learning strategies. Such learners allocate their resources deliberately and assess their readiness for particular test and performances carefully. It seems that transfer itself is dependent on metacognitive processes. Accordingly, the elements and conditions necessary to promote transfer that are identified in the literature include plenty of time to learn and varying contexts. In addition, a specific kind of problem representation is often described. Knowledge representation is built up through repeated opportunities to observe similarities and differences across diverse events. “Successful analogical transfer leads to the induction of a general schema for the solved problems that can be applied to subsequent problems” (National Research Council, 1994; see Bransford et al., 2000, p 66). Singley and Anderson (1989) argue that transfer is a function of the degree to which tasks share cognitive elements. Measuring this overlap requires a theory of how knowledge is represented and conceptually mapped across domains. Beyond the classic assumption of identical elements (Thorndike & Woodworth, 1901), cognitive representations and strategies are now also conceived of as “elements” that vary across tasks.

4. Results on the interrelation between prior knowledge and metacognition

Although numerous studies provide evidence for the strong and direct effects of domain-specific prior knowledge and metacognition for learning outcomes, an exclusive focus on their respective main effects produces a skewed picture. Prior knowledge and metacognition are neither empirically nor theoretically independent of each other. Their interaction during learning can be described from various perspectives. One such perspective is provided by the notion that the selection and use of strategies (including metacognitive strategies like monitoring and control) is dependent on the subjective difficulty of the task. It is only effective to apply strategies appropriate to the task at hand. Weinert (1984) pointed out that it makes sense to use metacognitive strategies only when the subjective difficulty of tasks is moderate. If a task is too difficult, metamemorial knowledge will often lead to the realistic conclusion that it would be pointless to invest a great deal of effort. If a task is too easy, metacognitions are irrelevant, as they are not needed for task processing (which occurs automatically). McKeachie (1987) used the term *region of metacognicity* to describe the region in which the use of metacognitive control strategies is beneficial for learning outcomes.

Another perspective is offered by Hatano (1998), who framed the dependency between strategy use, prior knowledge, and interest in terms of a kind of a cost–benefit analysis. As Hatano pointed out, using comprehension-oriented forms of learning or extensive monitoring and control is very time and effort intensive. Comprehension-oriented learning processes can be described as high-cost, but high-benefit processes. The great benefit of this time-intensive form of learning is the enhanced performance that ensues. Hatano further assumed that there is a general tendency to use schemas to achieve comprehension. A learner is only prepared to engage in comprehension-oriented learning when the advantages of deploying such methods are expected to outweigh the disadvantages. This explains why deeper levels of comprehension are closely related to higher levels of motivation and prior knowledge: “High-cost comprehension activity is induced highly selectively, not because humans are lazy, but because the activity requires so much time and effort” (p. 403). This selectivity applies to the use of deeper processes of comprehension as well as to the identification of gaps in one’s understanding. However, there is no such tendency to overlook gaps in one’s understanding in the context of one’s own domains of interest or areas of expertise. Here, detailed prior knowledge is available and serves as a basis for comprehension. Against this background, it is possible to explain the widespread connections between interest, domain-specific prior knowledge, and strategy use found in the literature.

Alexander’s model of domain learning (e.g., Alexander, 1997) also proposes that the effects of strategies vary with the level of domain-specific prior knowledge, but his approach differs somewhat from Hatano’s: According to Alexander’s model, students with little domain–specific prior knowledge must rely on cognitive and metacognitive strategies when learn; as they become more knowledgeable, this dependency is reduced. Moreover, students with limited domain-specific prior knowledge may apply strategies less efficiently and effectively than more knowledgeable students, who are free to direct less effort into constructing a knowledge base.

There is also evidence for mutual exchangeability. A rich knowledge base can obviate the need to use strategies; at the same time, prior knowledge may be a prerequisite for using strategies. Research by Braten and Samuelstuen (2004) also suggests that students’ flexible use of text-processing strategies may depend on their topic knowledge. Schneider, Schlagmüller and Visé (1998) assessed the relationships among verbal IQ, memory capacity, domain-specific knowledge, declarative metacognition, use of a semantic organizational strategy, and recall in a sort/recall task in a sample of 155 third and fourth graders. They found that individual differences in declarative metacognition explained a large proportion of the variance in the recall data. A somewhat different pattern of findings was found when the sort/recall task was based on soccer items, and children's knowledge of soccer was used as an additional predictor variable. Under these conditions, soccer knowledge emerged as the most powerful predictor, explaining the lion's share of children's recall variance. However, metamemory still had an indirect influence via strategy use (sorting), although the respective path coefficients were considerably lower than those obtained in the first model (see Körkel and Schneider, 1992, for similar findings using a memory-for-text paradigm). More empirical evidence for the interaction between expertise and metacognition in the context of learning outcomes has been reported by Minnaert and Janssen (1996), Veenman, Wilhelm, and Beishuizen, (2004), and Lind and Sandmann (2003).

Parallel to research showing that domain-specific prior knowledge and metacognition are dependent on each other and that their effects are sometimes barely separable in specific learning situations, there also is conceptual overlap in the way the constructs are (sometimes) defined. In particular, this applies to the definitions of prior knowledge and expertise. Both conceptualizations often also cover aspects of metacognitive knowledge and skills (see above). Dochy and Alexander (1995), for example, defined prior knowledge as "the whole of a person's knowledge. As such, prior knowledge is dynamic in nature, is available before a certain learning task, is structured, can exist in multiple states (i.e., declarative, procedural, and conditional knowledge), is both explicit and tacit in nature, contains conceptual and metacognitive knowledge components" (p. 227f.). In a similar vein, Bransford, Brown, and Cocking (2000) characterize experts by their use of metacognition. Experts "not only use what they have learned, they are metacognitive and continually question their current levels of expertise and attempt to move beyond them" (p. 48). Metacognitive (as well as motivational) components have become increasingly important in models of expertise (Ericsson, Charness, Hoffman, & Feltovich, 2006). Thus, metacognition and flexibility refer to two related parts of expert performance: Experts develop and use more metacognitive strategies—such as monitoring, evaluation, and correcting—than novices (Glaser, 1985).

On the other hand, declarative elements of metacognition are explicitly conceived of as knowledge components, and domain-specific prior knowledge plays a prominent role in theoretical extensions of the metacognition framework. For example, the Good Information Processing Model links aspects of procedural and declarative metacognitive knowledge to other features of successful information processing (e.g., Pressley, Borkowski, & O'Sullivan, 1985; Pressley, Borkowski, & Schneider, 1987, 1989). According to this model, sophisticated metacognition is closely related to the learner's strategy use, domain specific prior knowledge, motivational orientation, general knowledge about the world, and automated use of efficient learning procedures. All of these components are assumed to interact. For instance, specific strategy knowledge influences the application of metacognitive strategies, which in turn affects knowledge. As the strategies are applied, they are monitored and evaluated, which leads to expansion and refinement of specific strategy knowledge. In a similar vein, De Corte (1990) identified three categories of skills that learners need to master to approach a task effectively and with a fair chance of success: (1) flexible application of a well-organized domain-specific knowledge base, (2) heuristic methods such as systematic search strategies for problem analysis and transformation, and (3) metacognitive skills.

5. Conclusions

Against the background of the general debate about educational goals, the relative importance of domain-specific prior knowledge as compared to cross-curricular competencies for learning has been discussed. Empirical research as well as theoretical models on metacognition and expertise—and especially on mechanisms of acquisition—illustrates commonalities between the two concepts and draws attention to the need to take interactions between the two into account when analyzing their impact on learning outcomes. Prior knowledge and metacognition cannot be conceived of as being independent, neither from a theoretical point of view nor empirically. It is also difficult to separate their effects in specific learning situations. Overall, empirical research addressing more thoroughly the developmental relations between metacognition, general intellectual abilities, and domain-specific prior knowledge is rare. Most research presented throughout this article is cross-sectional. The few longitudinal studies mainly focused on a particular age group (e.g. elementary school children for research on metacognitive development), or did not simultaneously study the effects of metacognition, prior knowledge and general intellectual abilities.

It seems to be of particular importance to set up longitudinal studies aiming at disentangling the effects of metacognition and prior knowledge in different subject domains and thereby gaining a better understanding of their relative importance over time, the developmental mechanisms as well as stage-specific effects. In addition to highly needed replications of findings and theoretical models related to threshold models, possible compensations of metacognition, prior knowledge and intellectual abilities (e.g. Elshout 1987; Boekaerts, 1997; Schneider, 2000), longitudinal studies that take into account the effects of metacognition, domain-specific prior knowledge and IQ simultaneously in different subject domains seem well-suited to gain more insights into developmental trajectories and transferability of knowledge. Given the lack of solid and replicable empirical evidence related to transferability of metacognitive knowledge and skills, Pintrich, Wolters, and Baxter (2000, p.88) state: "Our theoretical models have not always been clear concerning how transfer is assumed to occur across situations, tasks, or domains, so it is not surprising that our measurement efforts have been less than successful in coping with this issue. The issue of domain specificity and transfer may be the largest and most intractable problem confronting our theoretical and assessment efforts". Clearly research of this kind would also add important empirical evidence to the mostly theoretical and/or ideological debate about the relative importance of material or formal education in school.

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Notes

Note 1. Nevertheless, the concepts of metacognition and self-regulated learning are not equivalent; each stems from a different research tradition (compare chapter 4).