Jan Elen
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Links Between Beliefs and Cognitive Flexibility

Lessons Learned

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Chapter 1
Introduction

Jan Elen, Elmar Stahl, Rainer Bromme, and Geraldine Clarebout

Society is rapidly evolving. It is becoming more diverse and complex. Such a society requires its members to be sophisticated problem solvers. Problem solving in a complex and evolving context implies consideration of multiple interpretations of the problem and conceptualization of different solutions and solution strategies. A large number of social problems is discussed in relation to scientific findings. An adequate understanding of the nature of scientific knowledge is a necessity for public engagement with science, that is, for an active civic participation in modern science- and technology-based societies. As a consequence, sophisticated problem solving should be discussed in close relation to the concepts of cognitive flexibility and epistemological beliefs.

1.1 Cognitive Flexibility

Sophisticated problem solvers can be assumed to be well aware of the contextualized and relative nature of selected solutions. Changes in the context, additional information, or evolutions over time may induce them to reconsider their selection of a solution or even their interpretation of the problem at hand. From this perspective, it seems that this rapidly evolving society requires problem solvers to be cognitive flexible.

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While cognitive flexibility can be said to be important for current problem solving and while it can be argued that given the increased need to solve ill-structured problems cognitive flexibility has become an important educational goal, it is far from clear what cognitive flexibility exactly entails. As already pointed out by Diaz (1983) for the domain of bilingualism, cognitive flexibility is a rather vague notion that is often loosely used. Without any ambition to structure this notion (e.g., Chieu, 2007) or to extensively discuss related processes, a broad perspective to the notion is given in the following lines.

Cognitive flexibility can be described as the disposition to consider diverse context-specific information elements while deciding on how to solve a problem or to execute a (learning) task in a variety of domains and to adapt one's problem solving or task execution in case the context changes or new information becomes present.

Cognitive flexibility has both perceptual and representational components. In order to be able to be flexible, one has to notice changes in the context and perceive new information. The representational aspect is stressed by Spiro and Jehng. According to Spiro and Jehng, cognitive flexibility is "the ability to spontaneously restructure one's knowledge, in many ways, in adaptive response to radically changing situational demands" (Spiro & Jehng, 1990, p. 165).

Given that context-specific information elements are taken into account, being cognitive flexible implies that one considers both the context and the information at hand. Considering the context and information at hand and adequately representing the problem or task, may result in problem solving or task execution that is adaptive. Changes in the context and/or the information itself may result in the adoption of a problem solving or task execution strategy. Guilford (1959) already pointed out that such cognitive flexibility may result in creativity. Being aware and explicitly taking into account the context allow thinking "out of the box" while consciously and deliberately neglecting particular constraints. Cognitive flexibility involves a large number of cognitive operations which are executed systematically but not mechanically. It implies engagement while remaining critical about the outcomes of the operations.

Cognitive flexibility is not simply a set of skills or competencies; it is described as being a disposition. This point of view has multiple implications. First, it implies that it refers to a probability that one will act in a particular way (one is disposed to act cognitive flexible) although it does not imply one will always do so. Second, it implies that cognitive flexibility is deeply rooted in cognition and hence related in complex ways with other aspects of cognition. This second implication is at the root of this book that explores, analyzes, and theorizes about the relationships between cognitive flexibility and beliefs.

1.2 Epistemological Beliefs and Cognitive Flexibility

While a relationship between different types of beliefs and cognitive flexibility might be expected, of special interest is the relationship between epistemological beliefs and cognitive flexibility. Epistemological beliefs in its traditional description

(Hofer & Pintrich, 1997) refer to beliefs about knowledge and knowing. In a developmental view of epistemological beliefs, sophistication refers to the ability to take a stance while remaining critical about the position and aware of the constructed nature of that position. This description seems similar to a description of high-level cognitive flexibility.

Epistemological beliefs and cognitive flexibility can be interrelated in various ways. First, sophisticated epistemological beliefs and cognitive flexibility might be indicators of one another. This view would imply that particular evidence of cognitive flexibility reveals specific beliefs and that the demonstration of particular beliefs suggests that the holder of the beliefs is to some extent cognitive flexible.

Beliefs and cognitive flexibility may also be regarded to be independent cognitions that can mutually influence one another. In such a case, it is interesting to see whether and how a change in either a belief or cognitive flexibility results with respect to a change in cognitive flexibility or the belief at hand.

While epistemological beliefs are generally described as being general or domain related, of particular interest is the question about the context specificity of the beliefs. This of course also pertains to cognitive flexibility. Can we be cognitive flexible in one area and not in another, can we hold sophisticated beliefs with regard to one context but not with respect to another one? How then is cognitive flexibility related to domain-related and general beliefs?

This book aims at strengthening the field by offering a number of contributions that each discusses the notions of (epistemological) beliefs and cognitive flexibility and more importantly about their interrelationships. In each of the contributions, up to three theoretical propositions are formulated and discussed by referring to empirical research and theoretical insights.

A first series of chapters discusses conceptual issues with tremendous implications for (empirical) research. Based on an extensive review of the literature on epistemological beliefs, Jeremy Briell and his colleagues argue for the need to distinguish between a conception-oriented and a process-oriented perspective toward epistemological beliefs. It is argued that the conception-oriented form is sufficiently referred to as epistemological beliefs and defined as the abstract beliefs of lay folk that address questions relevant to professional epistemologists. The process-oriented form is suitably referred to as epistemological judgments and defined as the judgments of lay folk that mimic those of professional epistemologists. Given the complexity, it is asserted that multiple methods of measurement should be synchronized in instrumentation to support inferences and that novel research methods should be actively pursued.

The relationship between epistemological beliefs and epistemological judgments in relation to cognitive flexibility is also at the core of the chapter by Elmar Stahl. He argues that while in regular life, cognitive flexibility is normality and not an exceptional case, in educational psychology stability is regarded to be the normal and cognitive flexibility the exceptional case. It is argued that in order to strengthen the field, research on interactions is needed. A case is made for research that focuses on detailed interactions between complementary cognitive elements as the smallest unit in order to better understand the flexibility of epistemological judgments.

Marlene Schommer-Aikins highlights the diversity in different types of knowledge and specifies particular relationships between epistemological beliefs and cognitive flexibility in learning. Beliefs in multiple solutions, multiple sources of knowledge, and connected knowing can motivate learners to search for more than one option for finding solutions or view points. Beliefs in tentative knowledge, separate knowing, and complex knowledge can encourage learners to reactivate their search for solutions based on the passage of time or a trigger event. Beliefs in gradual learning, complex knowledge, and tentative knowledge can encourage learners to resist premature closure. Potential problems with regard to excessive forms of cognitive flexibility reveal the importance of metacognitive strategies (rooted in epistemological beliefs).

In his chapter, Richard F. Kitchener discusses epistemology and flexibility from a context of epistemological pragmatism. He clarifies the task of traditional epistemology as understood by philosophers. He stresses the presence of multiple conceptual pitfalls and points to the issue of domain generality and domain specificity. He ends with a discussion of the recent revolution produced by naturalistic epistemology and the implications of this challenge for understanding the relationship between personal epistemology and traditional epistemology.

A more explicit empirical stance is taken in two consecutive chapters. How people deal with inconsistencies or conflicts in scientific information is addressed by Dorothe Kienhues and Rainer Bromme. They focus on two types of explanations people could consider: the lack of one's ability to understand the information or to explain away the inconsistency, and the actually given inconsistency that is inherent to the topic, as the knowledge in itself is developing or uncertain. They assert that cognitive flexibility manifests in finding a suitable and adapted explanation for the experienced inconsistencies and that such flexibility depends on people's beliefs about abilities and on their epistemic beliefs. Several studies are summarized that underline both the role of beliefs about one's abilities and epistemic beliefs in processing scientific information. These studies show that searching for scientific information on the Internet is a suitable test bed to empirically investigate how people refer to ability and epistemic explanations in cases of (conflicting) knowledge claims.

Problems with multiple texts are the starting point for the chapter by Tobias Richter. In the case of conflicting information and opposing perspectives on the same or related issues, cognitive flexibility can be defined as the ability to develop a justified point of view by adopting some arguments and rejecting others on rational grounds. By proposing a simple process model, he addresses the cognitive processes that underscore epistemic validation as the key element in dealing with the above-mentioned problems. He argues that epistemic validation rests on two types of cognitive processes: (automatic) epistemic monitoring and (strategic) epistemic elaboration. Conceiving epistemological beliefs as declarative metacognition, it is claimed that epistemological beliefs determine whether learners achieve cognitive flexibility in learning with multiple texts.

A developmental perspective is opened by Beate Sodian and Petra Barchfeld. Around the age of 4 years, children master basic cognitive flexibility tasks, such as switching dimensions or providing alternative names for an object. In their chapter, these authors investigate whether a developmental relation between the ability to entertain alternative representations and the ability to distinguish between true and false representations can be found with respect to more complex forms of perspective taking, such as thinking about alternative causal theories. It is observed that previous analyses of cognitive abilities involved in the coordination of theories and evidence in terms of epistemological stances conflict with recent findings on children's theory of mind. A framework for analyzing levels of theory–evidence differentiation is introduced and applied. The findings indicate that the ability to conceive of alternatives to one's own intuitive theory developmentally precedes an understanding of evidence relevant to evaluating such theories.

The last two chapters address the relationships between beliefs and flexibility from a discipline-specific angle. Ann Roex and her colleagues investigate whether the beliefs medical trainees hold about knowledge and knowing consist out of different dimensions which are stable across different medical domains. A series of studies is reported in which the relationship between sophistication in beliefs and levels of cognitive flexibility is explored. The chapter further indicates that beliefs and levels of cognitive flexibility might be affected by training and examination practices.

Mathematics and strategic flexibility are dealt with in the chapter of Lieven Verschaffel and colleagues. Strategic flexibility is defined as the selection and execution of the most appropriate solution strategy (available in one's strategy repertoire) on a given mathematical task, and for a given individual, in a given context or situation. Some empirical research is reported indicating that strategic flexibility is an important and distinctive feature of being good at mathematics or having true mathematical expertise. In the final part, it is argued that given the dispositional nature of strategic flexibility, there is a need to aim at it from the start of the teaching and learning process and for an integrative teaching approach.

The conclusion reflects on how the theoretical statements in each of the chapters are interrelated and shows new venues for further research.

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Chapter 2
Personal Epistemology: Nomenclature, Conceptualizations, and Measurement

Jeremy Briell, Jan Elen, Lieven Verschaffel, and Geraldine Clarebout

2.1 Introduction

How cognitive flexibility relates to personal epistemology depends entirely on how the constructs are interpreted. We address the latter half of this question here.

Scholars over the generations have attempted to decipher arguably the most rudimentary element of being human – "knowledge." Kitchener (2002) defines epistemology as a theory of knowledge, reflecting its etymological origins in the Greek words "episteme" (knowledge) and "logos" (theory). An age-old branch of philosophy, epistemology is also a significant field of study for cognitive and educational psychologists. Whereas the philosophical branch concerns professional theorizing about knowledge, the psychological branch pertains to empirical observations of the epistemology of laypersons. A host of research lines, each employing preferred nomenclatures and interpretations, belong to this field, which is collectively known as "personal epistemology" – the umbrella term notably employed by Hofer and Pintrich (1997) in their extensive review.

It is well known to the reader familiar with personal epistemology that this field struggles with fundamental and persistent issues regarding nomenclature, conceptualization, and measurement. In this chapter, we visit each of these basic questions by means of a review. Our ultimate objective is to clarify the construct so that the reader may better apprehend its significance to cognitive flexibility.

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2.2 Literature Search

The thorough review by Hofer and Pintrich (1997) is undoubtedly well known to those familiar with personal epistemology. As these reviewers note, "Defining the construct based on existing research is problematic, as there are discrepancies in naming the construct as well as defining the construct, to the extent that it is sometimes unclear to what degree researchers are discussing the same intellectual territory" (p. 111). Because personal epistemology represents a divergent and loosely defined body of research, a number of steps were taken to insure the literature in this review resembled the research Hofer and Pintrich had reviewed and how they had defined it.

In an initial step, we entered the terms "reflective judgment," "ways of knowing," and "epistem*" into a search of PsycINFO database. The search terms were chosen because of their usage in the six models reviewed by Hofer and Pintrich (1997).[1] The search was limited to empirical research, peer-reviewed journal articles and book sources (i.e., references to various types of books and book chapters), the English language, publications from 1998 to 2009, and adolescents and adults. The latter two limitations were chosen for the following reasons: The time frame is meant to capture literature from publication of the Hofer and Pintrich review onward. We eliminated studies of preadolescent populations, because it is our contention a joint review of children and adult epistemologies should have a more specific focus than the umbrella construct currently under review.[2] This step yielded in 617 references.

Of these, nearly half were excluded because the identified term did not represent a construct under investigation. For instance, Hosoda (2006) investigated a construct which is partially derived from an understanding of the "epistemology of [nursing] practice" (p. 480). Eight references were also eliminated because they were repetitive.

We were not confident, however, that all of these studies belonged under the umbrella of personal epistemological research. The constructs under investigation seemed to vary substantially with respect to terminologies and definitions. This is not surprising considering the previously mentioned nature of personal epistemology. Quite often, however, it was difficult to ascertain how the studies corresponded to the notion as it was defined and reviewed by Hofer and Pintrich (1997).

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[1] Various forms of the root word "epistem" were applied in the models (i.e., epistemic cognition, epistemological assumptions, epistemological beliefs, epistemological perspectives, epistemological theories, and epistemology). Because of this, and because we are aware of other more recent terms with the same root, we chose to enter "epistem*" to avoid excluding nomenclatures representative of PE.

[2] The target populations for the research programs reviewed by Hofer and Pintrich (1997) were predominantly college-age young adults. Recent studies have begun to investigate, or are beginning to take an interest in, personal epistemology from the perspective of child development (see Kitchener, 2002).

Hence, we sought to eliminate studies with little resemblance to personal epistemology as they had defined it. For instance, in their interpretation, personal epistemology represents a personal construct (i.e., a construct which researchers attribute to respondents). Hence, studies were excluded when this was not a feature of the identified construct. For example, Fulkova, Straker, and Jaros (2004) examined the "onto-epistemic status… of contemporary material culture" (p. 4). The term represents how contemporary society interprets works of art, which is visibly more of a social/collective construct. Studies were also eliminated when the identified construct was clearly something other than personal epistemology. For instance, we eliminated studies that dealt with "epistemic curiosity," which Litman, Hutchins, and Russon (2005) define as "a desire for new information that motivates exploratory behavior and knowledge acquisition" (p. 559). We also removed investigations of "epistemic motivation," meaning a "desire to acquire knowledge" (Lun, Sinclair, Whitchurch, & Glen, 2007). Studies such as Darnon, Muller, Schrager, Pannuzzo, and Butera (2006) that dealt with "epistemic conflict regulation (a conflict regulation strategy focused on the attempt to integrate both points of view)" were also excluded (p. 766).

Since the time of the Hofer and Pintrich (1997) review, the field has also begun to consider personal epistemology on a domain-specific level (see, for instance, Hofer, 2006) and, more recently, though not to the same extent, relative to a particular topic or context. We decided to be selective; a single review would not do justice to the amount of literature that has accumulated here. Therefore, we concerned ourselves only with studies that were domain general or those that contrasted differing cognitive ranges (e.g., mathematics and science epistemologies, general and history epistemologies, and comparisons of multiple context-specific epistemologies).

The literature search was conducted in November and December of 2009. In total, 151 studies were retrieved.

2.3 Section I: Nomenclature and Conceptualizations

Terminology has caused much consternation among researchers, resulting in a plethora of nomenclatures. Unfortunately, similar sounding ones can mean quite different things and vice versa. And, it is often the case that more than one term is employed in a single study. Sometimes multiple terms are used interchangeably and sometimes they are not; sometimes the meanings of different terms are explained and sometimes their meanings are assumed. Further, two studies may use different terms though their meanings are the same. For this reason, terms alone do not always clarify conceptual distinctions and mean little apart from their implementation. Our line of argument here is that distinct terms are necessary where major conceptual differences exist, but they are unnecessary if they are primarily preferential or misleading. We will argue of personal epistemology, as Pajares (1992) had of teachers' beliefs, "that research studies would be well served by … reasoned choice[s] commonly understood and consistently employed" (p. 311).

Table 2.1 Frequently and less frequently employed terminology

Frequently employed terms[a]		
Epistemic beliefs	Epistemic cognition	Epistemic reasoning
Epistemological assumptions	Epistemological beliefs	Epistemological perspectives
Epistemological stance	Epistemological understanding	Epistemology
Personal epistemology	Reflective judgment	Ways of knowing
Less frequently employed terms[b]		
Epistemic assumptions	Epistemic criteria	Epistemic dependence
Epistemic elaboration	Epistemic knowledge	Epistemic monitoring processes
Epistemic regulation	Epistemic stance	Epistemic styles
Epistemic validation	Epistemic worldviews	Epistemically related beliefs
Epistemological approaches	Epistemological dispositions	Epistemological forms
Epistemological frameworks	Epistemological intentions	Epistemological knowledge
Epistemological orientations	Epistemological resources	Epistemological thought
Epistemological underpinnings	Epistemological worldviews	Folk epistemology
Implicit epistemology	Psycho-epistemological styles	

[a]Terms used in three or more studies
[b]Terms used in only one or two studies

2.3.1 The Dual Nature of Personal Epistemology

Table 2.1 above lists frequently and less frequently employed terms in the studies. Most of the terms are connotative of cognitive structures (e.g., epistemological assumptions, epistemic beliefs, and epistemological knowledge) or cognitive processes (e.g., epistemic reasoning, reflective judgment, and ways of knowing), which is further borne out in definitions. The vast majority of studies seemed to be aptly characterized by one or both of these groupings, the difference stemming from whether the construct was perceived as something that exists abstractly or something that occurs in thinking and learning situations. Therefore, we attempted to classify them systematically according to how constructs were introduced. Constructs were classified as conception oriented if a study referred to abstract conceptions. For instance, Brownlee, Purdie, and Boulton-Lewis (2001) define "epistemological beliefs" as "beliefs about knowing [that] reflect an individual's views on what knowledge is, how it can be gained, its degree of certainty, the limits and criteria for determining knowledge" (p. 247). Constructs were classified as process oriented if they stood for how individuals come to know. As a prototypical example, Beaudoin and Schonert-Reichl (2006) refer epistemic reasoning as "the processes utilized by an individual for coming to terms with doubt brought about by competing knowledge claims" (p. 1000). A number of studies refer to construct(s), which we judge to be a combination of the two categories. In some instances, researchers use separate terms and definitions for the two orientations. For instance, Eigenberger, Critchley, and Sealander (2007) utilize the term "epistemic style" to represent an

Table 2.2 Classification of constructs under investigation

Categories	Studies
Conceptual construct	
• Knowledge/knowing	60
• Knowledge/knowing and learning	31
• Knowledge/knowing and other	8
• Other	9
• Not specified	3
Process construct	19
Conceptual and process construct(s)	
• Distinct terms	4
• No distinct terms	11
Other	2
Construct insufficiently defined	7

Note: Three studies separately investigated two constructs that fit into more than one of the above categories

"individual's habitual or favored process of making a judgment or solving a problem, which is ultimately derived from one's theory of knowledge [i.e., 'epistemic assumptions']" (p. 3). Table 2.2 is the result of our judgments.

In the latter example above, the researchers are making a distinction that is historical and, which we argue, imperative. Historically speaking, the Perry scheme (Perry, 1970) was devised on the premise that how students construed experiences of perceived importance is structured by their "epistemological assumptions." Hence, the model is descriptive of an amalgamation of respondents' abstract assumptions (about knowledge, value, and responsibility) and their associated meaning making. Another major influence on the field is the reflective judgment model (RJM; King & Kitchener, 1994, 2002, 2004; King, Kitchener, Wood, & Davidson, 1989; Kitchener, 1983; Kitchener & King, 1981). According to the RJM, certain "epistemic assumptions" (i.e., general implicit assumptions about the nature of knowledge) determine certain stages of judgment making (i.e., pre-reflective, quasi-reflective, and reflective). These and other influential researches portray forms of reasoning that are structured by abstract conceptions in a fashion that suggests an indiscernible fusion (e.g., Baxter Magolda, 1992; Belenky, Clinchy, Goldberger, & Tarule, 1986; Perry, 1970) or a straightforward relationship (i.e., RJM), a tradition that persists in the studies we reviewed.

Because of their theoretical relationship and because each is inferred from the other in studies, little emphasis is given to differentiating conception-oriented constructs and process-oriented constructs. However, they are conceptually different. What an individual believes on an abstract level and how she goes about knowing and learning are not the same. Although, theoretically speaking, an obvious relationship exists, their relations are probably more complicated than currently modeled. Regrettably, what should be treated as theory is now taken as conclusions forgone, which creates chaos in terms of understanding constructs and how they are measured.

As an example, Pizzolato and Ozaki (2007) describe, "self-authored people" as those that "employ complex cognitive processes in ways that recognizes the socially constructed nature of knowledge," which is measured through interviews concerning participant interpretations of important experiences (p. 196). Note the reader is asked to presume the relationship and accept the inferred conceptions about knowledge. As another example, Lovell and Nunnery (2004) refer to developmental epistemologies as "forms of intellectual and ethical development" that are comprised of cognitive structures (p. 139). In essence, they are referring to the Perry scheme. In order to infer positions (of the lower half) of that scheme, they employ the Learning Environmental Preferences (Moore, 1989), a survey that measures students preferences for certain learning environments. The conundrum being that the reader would be hard-pressed to know whether the learning preferences operationalized are used to primarily infer the scheme's abstract assumptions and only secondly to infer its corresponding forms of meaning making or vice versa or simultaneously to infer both. Even the instrument's designer seems unable to resolve this question, when saying, "…the measure does perform as if it reflected the Perry scheme, or at least some form of cognitive development" (Moore, 1989, p. 510). The confusion occurs because too often the line between how one knows and what one abstractly conceives in researchers' interpretations and operationalizations of personal epistemology is entirely unrecognizable, which could be ameliorated by conceiving of the umbrella construct as having two forms that are *only* theoretically related.

Based on this line of reasoning, we discuss the scope of personal epistemology from a dual-nature perspective, that is, arguments about how each form should be termed and defined are discussed individually.

2.3.2 Review of Conception-Oriented Form of Personal Epistemology

Seventy-three percent of the studies reviewed were categorized as purely involving a conception-oriented construct, while another 10% were classified as concerning a mix of conception- and process-oriented constructs. A number of conceptual divergences are evident in how these researches define the nature of the conception-oriented construct; these regard precisely *about what* the conceptions are and about their *cognitive form, status, and range*.

2.3.2.1 Conceptions About What

What the conceptions are about is a complex question requiring an intricate answer. However, we can begin with a general, obvious answer, which can be readily gleaned from the definitions researchers give. Of the 109 studies that refer to a conception-oriented construct, 90 define them as being about "knowledge" and/or "knowing."

Often, the two descriptors are together in definitions and referred to as the "nature of knowledge and knowing." Thirty-one of these ninety also define the conceptions as being about "learning" or "knowledge acquisition." Constructs are also defined as being about other concepts, such as the ability to arrive at a right answer with complete certainty (Brem, Russel, & Weems, 2001), one's competence being dependent on her ability to admit knowledge (Mugny, Chatard, & Quiamzade, 2006), "belief" Alexander, Murphy, & Guan, 1998; Alexander, Murphy, Guan, & Murphy, 1998), "truth" (Bond, Belenky, & Weinstock, 2000; Jimmerson & Bond, 2001; Mansfield & Clinchy, 2002; Marra, 2005; Weinstock & Bond, 2000), "self as knower" (Bond et al., 2000; Bond & Burns, 2006; Burns & Bond, 2004), and the "nature of authority" (Hensley, 2001).

2.3.2.2 Cognitive Form, Status, and Range

Other questions concerning the nature of the conceptions regard their cognitive form, status, and range, which are not altogether separate issues. Traditionally, the conceptions were modeled as unitary structures (or stage-like levels), having an implicit status, and representative of knowledge in general (Baxter Magolda, 1992; Belenky et al., 1986; King and Kitchener, 1994; Kuhn, 1991; Perry, 1970).

The unitary form of the conceptions proposed in stage models was challenged by later theorists. It was discerned that such models could be teased apart into distinct conceptual facets or dimensions (see Hofer & Pintrich, 1997; Schommer 1990), which Schommer theorized operated as a system of relatively independent beliefs. Meaning, an individual could hold, for instance, the sophisticated belief that knowledge is highly complex and simultaneously believe, naïvely, that knowledge is certain (Schommer-Aikins, Duell, & Barker, 2003, p. 350). Despite the abundance of dimensional research, asynchronous development has not been formally tested (Schommer-Aikins, 2004). As a compromise between stage models that do not allow for within-stage variation and orthogonal dimensional models, Hofer and Pintrich proposed that epistemological beliefs have a theory-like structure. More recently, Hammer and colleagues (Hammer & Elby, 2002, Louca, Elby, Hammer, & Kagey, 2004; Rosenberg, Hammer, & Phelan, 2006) proposed another alternative, a structure of fine-grained cognitive resources (a concept adopted from diSessa's (1993) phenomenological primitive or p-prims) that are "legion, sensitive to context in their activation, and linked in a network of 'cuing' priorities" (Rosenberg et al., 2006, p. 265). All four proposed forms for the conceptions are employed in studies reviewed to frame the conceptions investigated.

The implicit status of the conceptions has not been challenged by more recent literature, as is often evident in labels given: "epistemic assumptions" (e.g., Eigenberger et al., 2007), "epistemological assumptions" (e.g., Baxter Magolda, 2004), "epistemological forms" (Lovell & Nunnery, 2004), and "implicit epistemologies" (Pirttilä-Backman & Kajanne, 2001). It is also apparent in researchers' descriptions. For instance, Ricco (2007) and Ricco and Rodriguez (2006) define "personal epistemology" as naïve or intuitive beliefs.

The majority of studies reviewed were conceptualized as regarding knowledge in general (i.e., domain general). It is important to note that this observation is certainly biased based on how the literature search was conducted. That said, it is still obvious that the number of studies to investigate conceptions of smaller cognitive ranges is increasing. Typically, operationalized at a disciplinary-domain-specific (e.g., Buehl & Alexander, 2005; Hofer, 2000; Schommer-Aikins, Duell, & Hutter, 2005), judgment-domain-specific (Hallett, Chandler, & Krettenauer, 2002; Kuhn, Cheney, & Weinstock, 2000), and more recently topic-specific (e.g., Trautwein & Lüdtke, 2007) or context-sensitive (e.g., Rosenberg et al., 2006) range.

2.3.3 Argument Concerning Conception-Oriented Form of Personal Epistemology

The above provides an overview of how researchers define what we refer to as the conception-oriented form of personal epistemology.

2.3.3.1 "Epistemic" Versus "Epistemological"

As is obvious in Table 2.1, there are basically two candidate adjectives that researchers apply to characterize the conceptions they are investigating: "epistemic" and "epistemological." Since there is no visible difference in the conceptions the two adjectives refer to, a choice should be made between them. According to the Oxford Dictionary of Current English, an adjective is "a word used to describe a noun or make its meaning clearer, such as sweet, red, or technical." Regrettably, neither choice of adjective escapes the possibility of obscuring the conceptions being investigated. In Richard Kitchener's valuable contribution to this book, he points out that there are multiple ways of translating the use of these adjectives involving a number of complexities.[3] His preferred translation for epistemic beliefs is beliefs about the epistemic, that is, beliefs about knowledge, to which he says is equivalent to epistemology. Kitchener also explains that epistemological beliefs can be translated as beliefs about the study of knowledge. Kitchener's favored translations recognize the adjectives as describing what the conceptions are about. However, it is also possible to employ adjectives to describe what the conceptions are. For example, naïve beliefs are beliefs that are naïve, intuitive beliefs are intuitive, sensible beliefs are sensible, and so forth. In the same way, epistemological beliefs can be translated as beliefs that are epistemological. Epistemological is the derived adjective form of epistemology. Hence, it is viable to say epistemological beliefs are beliefs that are epistemology. Likewise, epistemic beliefs are beliefs that are epistemic, that is, beliefs that are knowledge (perhaps, justified

[3] Similar arguments are made by Kitchener (2002) in an earlier contribution.

true beliefs). Notwithstanding, we respect that researchers using epistemic intend to say the conceptions are about knowledge and those applying epistemological mean that the conceptions are epistemology. Recognizing this, we argue that epistemological is a better choice of adjective.

From our review, it is clear that epistemological is more commonly employed, thus suggesting a greater possibility of striking accord. Further, when epistemic is applied to mean conceptions of lay folk about knowledge, this definition is only roughly equivalent to epistemology, as not all the conceptions of lay folk about knowledge belong to the professional domain of epistemology. Conversely, when epistemological is applied to mean the conceptions are the epistemology of lay folk, then it is clear that they must somehow emulate those of professional epistemologists. As such, it then relieves confusion about what the conception are about.

Most articulations of what the conceptions are about somewhat coincide with the dimensions rendered by Hofer and Pintrich (1997). These reviewers concluded two general dimensions were common to influential lines of research and the most compatible to philosophical treatments of epistemology: *Nature of knowledge* and *Nature of knowing*. The general dimensions were specified further as pertaining to four dimensions: *Certainty of knowledge* (ranging from conceptions of knowledge being fixed to being tentative and evolving), *Simplicity of knowledge* (ranging from conceptions of knowledge as discrete pieces of information to highly interrelated concepts), *Source of knowledge* (ranging from conceptions of knowledge being derived from external authorities to conceptions of self as knower), and *Justification for knowing* ("how knowledge claims are evaluated, including the use of evidence, the use they make of authority and expertise, and their evaluation of experts" [p. 120]). Notably, the latter dimension does not refer to conceptions, but to cognitive processes. This is because the reviewers did not distinguish the two forms of personal epistemology as we have in this chapter. From a conception-oriented standpoint, this dimension could be defined as what is justified knowledge to layfolk. (The RJM and Perry scheme are both relevant in suggesting what naïve to sophisticated range might exist.)

By saying constructs investigated somewhat coincide with Hofer and Pintrich's (1997) rendering of personal epistemology, we mean most refer to conceptions as being about the nature of knowledge and knowing. However, researchers do not always refer to the same specific dimensions. When studies do not refer to either general dimension, the conceptions referred to still largely fit the reviewers' interpretation of personal epistemology. For instance, conceptions that were defined as being about the nature of authority, self as knower, and knowledge dependence, all have correspondence to *Source of knowing* as it was defined by Hofer and Pintrich. Sometimes, researchers do not refer to dimensions at all, as with unitary conceptualizations. In these cases, it is more difficult to know specifically what conceptions are being investigated. Hence, from our standpoint, dimensional operationalizations are advantageous because they enable a clarity of thought and expression toward the construct that unitary models seem impervious to. Even still, it remains an important empirical question as to whether dimensions develop synchronously or asynchronously.

An obvious deviation from Hofer and Pintrich's (1997) interpretation of the construct remains with respect to the inclusion of conceptions about learning. This should come as little surprise considering the popularity of Schommer's (1990) dimensional model, which includes beliefs about the speed of learning and innateness of learning ability. The inclusion of beliefs about learning has triggered an intense debate among researchers. Schommer-Aikins, Mau, Brookhart, & Hutter (2000) expressed the concern that the debate "should not overshadow the more important issue – beliefs about learning and beliefs about knowledge both appear to have a critical impact on learning" (p. 126). While this is a valid point, it does not relieve the issue, as other constructs exist that are also consequential to learning, such as motivation or self-esteem, but that alone would not justify their inclusion. We agree with Hofer and Pintrich's assessment that beliefs about the learning process do not emulate professional epistemology, and are thus not theoretically relevant. Personal epistemological researchers should take cue from professional epistemologists in drawing the conceptual borders around lay epistemology and in determining what empirical questions are relevant. This is precisely why the chapter by Richard Kitchener is so imperative to our work, as he is uniquely qualified to guide us in these respects. It is also why we prefer the adjective epistemological, as it has been frequently, traditionally, and normally interpreted to mean the conceptions are epistemology, and, in turn, commonly understood to be about the nature of knowledge and knowing, which aligns well with professional epistemology. Meanwhile, we must be open to empirical findings. For example, Baxter Magolda (2004) asserts that conceptions about knowledge and learning are intertwined. This is a pertinent question for personal epistemological researchers. If when individuals are asked to define knowledge, for instance, and those definitions include ideas about learning – as we noticed in our own work (Briell, Elen, Depaepe, and Clarebout, 2010) – then it is difficult to exclude them from the agenda of personal epistemological research. In short, professional epistemologists ask certain questions and draw certain conclusions; personal epistemological researchers ask parallel questions of lay folk and observe the answers.

2.3.3.2 "Beliefs" Versus Other Descriptions

Thus far, we have mainly used the terms "conceptions" or "cognitive structures," because we regarded them to be the most neutral. Others represent them as assumptions, beliefs, perspectives, fine-grained resources, understandings, knowledge, dispositions, etc. Such a number of characterizations are only warranted if they are insightful of major theoretical divergences, which they generally are not, since they simply refer some form of abstract cognitive structures. Using the terms "epistemological conceptions" or "epistemological cognitive structures" is not practical because of their unwieldiness, not to mention, that would simply add to the ever-growing list of terms. We argue that "beliefs" is the best candidate for consensus.

This assertion relies on the efforts of Pajares (1992), who sought to find reasonable common ground amidst a similar diversity of terms and conceptualizations of teachers' beliefs. The predicament had arisen because of the mystery and empirical hurdles involved in understanding individuals' underlying states. Terms and definitions were attributed to "a game of player's choice" (p. 309) with choices highlighting the convoluted task of distinguishing between the intertwined concepts of belief and knowledge. He concluded, simply and broadly, that belief "speaks to an individual's judgment of the truth or falsity of a proposition …" (p. 316). Here, the propositions are abstract assertions to questions concerning professional epistemologists, generally, about the nature of knowledge and knowing. Hence, *epistemological beliefs* would thus refer to *the abstract beliefs of lay folk that address questions relevant to professional epistemologists, typically about the nature of knowledge and knowing*. As rendered by Pajares, belief is adaptive to the spread of conceived cognitive forms, statuses, and ranges. Beliefs can be conceived as implicit or explicit and general or specific. There is little reason to object to its use to describe cognitive structures in the form of unified wholes or orthogonal dimensions or ones that are theory-like. For instance, while Hofer and Pintrich (1997) had proposed a theory-like ontology, they did not shy away from referring to their proposal as beliefs in the form of personal theories. One exception can be made. Hammer and colleagues (Hammer & Elby, 2002, Louca et al., 2004; Rosenberg et al., 2006) are correct in saying that epistemological beliefs have largely been conceived as stable and robust across contexts. Therefore, their distinctive terminology should be respected because it highlights a significant theoretical departure. Notwithstanding, our argument is that all of these conceptualizations belong to epistemological beliefs research and in almost all cases, the construct itself should be referred to as epistemological beliefs. We are certainly not suggesting that this is a perfect term or that researchers put aside their theoretical differences; we are suggesting there is common ground in an imperfect term when broadly defined.

2.3.4 Review of Process-Oriented Form of Personal Epistemology

Nineteen studies were classified as strictly referring to process-oriented constructs and another fifteen to dual-oriented constructs (i.e., conception and process construct[s]). Our initial classification provides a generic defining of these constructs, that is, how individuals come to know. Regrettably, definitions provided in studies are equally unspecified. For instance, McAuliffe and Lovell (2006) define "developmental epistemology" as "how human meaning evolves over time and in various environments" (p. 308); Tirri, Husu, and Kansenen (1999) characterize "epistemological stances" as "how individual teachers are engaged in their processes of knowing" (p. 912); and Danforth and Glass (2001) investigate "the process by which people construct meaning" (p. 515). The difficulty being that such definitions are without distinguishing qualities that would identify them as being epistemological in nature. As such, they can represent an array of constructs, even ones that are not typically identified as belonging to personal epistemology (e.g., critical thinking, deep learning, and argumentative reasoning). Notwithstanding, three particular types of process-oriented constructs are discernible: (a) judgments about assertions, (b) salient meaning making, and (c) *Separate* and *Connected knowing*.

The first type of process construct models the judgments that individuals must undertake when confronted with propositions, usually contradictory assertions about a particular subject. Participants are queried about the validity of the assertions, why respective positions conflict, the criteria that justify a resolution to the conflict, and the certainty of their own beliefs about the matter. With one notable exception (Gottlieb, 2007), the respective types of questions are not considered individual dimensions. Instead, responses to the array of questions are normally summarized into unitary positions (e.g., dualistic, multiplistic, and rational). However, some researchers concentrate on a single type of question. For instance, Kuhn et al. (2000), Richter, Schroeder, and Wöhrmann (2009), and Schroeder, Richter, and Hoever (2008) all focus solely on judgments about the validity of assertions.

The second type depicts salient meaning making, that is, how individuals make sense of matters of personal significance. The most prominent example being the modeling of *Self-authorship*, a way of knowing originally described by Kegan (1994) and first supported empirically by Baxter Magolda (2004). The path to *Self-authorship* follows four phases (i.e., following formulas, crossroads, becoming the author of one's life, and internal foundation) and climaxes with the individual assuming responsibility for her own beliefs (epistemological dimension), identity (interpersonal dimension), and relationships (intrapersonal dimension).

The third type concerns two ways of knowing initially described by Belenky et al. (1986). *Separate knowing* represents an impersonal, objective, critical way of knowing, while *Connected knowing* represents a genuine attempt to understand from the position of the other person (Clinchy, 2002). They are described further as being distinct (Galotti, Drebus, & Riemer, 2001; Ryan & David, 2003), preferred (Knight et al. 2000), gender related (Galotti, 2001), personality related (Galotti, 2001), and spontaneously adopted (Galotti et al. 2006). They are also characterized as learning styles (Galotti, Clinchy, Ainsworth, Lavin, & Mansfield, 1999), approaches to knowledge and learning (Galotti et al., 2006), approaches to evaluating and constructing knowledge (Marrs & Benton, 2009), and processes of comprehending and evaluating assertions that entail social interaction (Schommer-Aikins & Easter, 2009).

2.3.5 Argument Concerning Process-Oriented Form of Personal Epistemology

As previously said, what seems to be missing about process-oriented constructs is a concise articulation of what gives these constructs their epistemological character. The obvious response being that they theoretically relate to certain epistemological beliefs. For instance, Pizzolato (2003) defines *Self-authorship* as involving the recognition of "the contextual nature of knowledge" (p. 798). Eigenberger et al. (2007) assert that epistemic styles are "ultimately derived from one's theory of knowledge" (p. 3). Originally, *Separate* and *Connected knowing* were evident among individuals that held epistemological beliefs associated with *Procedural knowing* (Belenky et al., 1986). Hence, one possibility of better defining process-oriented constructs would be to distinguish them as modes of knowing that are contingent upon certain epistemological beliefs. From our perspective, this is an impractical delineation, because the researcher is not always privy to such information and must rely extensively on speculation.

Alternatively, we argue they are better defined as the activities of amateur epistemologists, which mimic the work done by professional epistemologists. Siegel (1978) briefly summarizes traditional epistemology as being "concerned with the evaluation of knowledge claims – that is, with the analysis of the criteria of appraisal of various claims about the nature of the world…." (p. 17). From the perspective of an epistemologist, "[t]he objective of the analysis of knowledge is to state the conditions that are individually necessary and jointly sufficient for propositional knowledge, knowledge that such-and-such is the case" (Steup, 2006, "The analysis of knowledge"). Hence, this form of personal epistemological research is not merely concerned with how individuals come to know, but with how an individual evaluates and justifies certain assertions. The first abovementioned type of process-oriented construct (i.e., judgments about assertions) leads us to suggest at least four dimensions are relevant: (a) *assessments of the validity of assertions of others*, (b) *explanations for why assertions compete*, (c) *evaluations of the certainty of one's own beliefs about an issue*, and (d) *decisions about the criteria that would justify an assertion*. The latter dimension concerns objective (evidence, plausibility, coherence, and reputation of the sayer) and subjective (intuition, emotions, trust) criteria. Such judgments are known by an array of terminologies, such as reflective judgments, epistemic cognition, and epistemic thinking. These terms, however, are defined by researchers in ways that would confuse the form of personal epistemology delineated here. Therefore, we recommend an altogether new term. The above dimensions are judgments of an epistemological nature that are essential components of the process of knowing and learning. Hence, we suggest they be labeled *epistemological judgments* and defined as *the judgments of lay folk that mimic those of professional epistemologists, normally pertaining to the evaluation and justification of certain assertions*.[4]

We are not suggesting that the second and third process-construct types do not contribute to this research. Both suggest that the evaluation of assertions involves social interactions, namely, Baxter Magolda's (2004) model proposes a personal struggle can ensue in the process of accepting or rejecting assertions of personal significance between intrapersonal and interpersonal forces. For example, "following formulas" implies the acceptance of assertions based on the designs of others,

[4]We rely on our earlier arguments for choosing the adjective epistemological verses epistemic.

whereas “internal foundation” implies internal justifications, and *Self-authorship* is the developmental pathway from one to the other (Baxter Magolda, 2004). *Separate* and *Connected knowing* also suggest different ways of achieving identity and interacting with others in the process of making epistemological judgments, that is, trusting and attempting to understand another’s proposition before judging it (*Connected knowing*) or first being skeptical of its value before integrating it with prior understandings (*Separate knowing*). These two construct types imply a holistic approach, that is, not only investigating what epistemological judgments are made, but why social beings make them. Notwithstanding, they do not specifically or intentionally model epistemological judgments as we have just outlined them.

2.4 Section II: Measurement of Epistemological Beliefs

Our third argument is reserved for the measurement of epistemological beliefs because we find the most substantial measurement challenges lie therein. As stated already, epistemological beliefs and epistemological judgments each can be inferred from the other and it is not always clear the specific purpose of the investigation. Therefore, it is not possible to say certain instruments are *always* used to access epistemological beliefs and certain others *exclusively* measure epistemological judgments. Notwithstanding, the studies reviewed do suggest a number of prominent ways of assessing epistemological beliefs. To gain insight to these approaches, we begin by simply describing studies in groups according to obvious similarities in instrumentation, which we refer to as measurement clusters. The term “clusters” reinforces the actuality that descriptions are generalizations about an assortment of instruments. (Statistics of studies included in each cluster can be found in Table 2.3.) We then narrow the discussion by identifying leading methods of assessing epistemological beliefs, uncover their shortcomings, and proceed to our final argument.

Table 2.3 Cluster statistics

	Studies in primary clusters					
	I	II	III	IV	V	Other
n	90	19	26	8	10	3

Note: *Clusters*: Cluster I = studies that employ Likert-type instruments to measure unitary positions or belief dimensions. Cluster II = studies that pose direct questions about the nature of knowledge and knowing. Cluster III = studies that analyze judgments about assertions. Cluster IV = studies that analyze salient meaning making. Cluster V = studies that employ Likert-type instruments to measure *Separate* and *Connected knowing*. Other = studies that employ methodologies that cannot be easily situated within in the cluster scheme (Five studies employed multiple instruments belonging to more than one cluster)

2.4.1 *Review by Measurement Clusters*

2.4.1.1 Cluster I: Likert-Type Measures of Unitary Positions or Belief Dimensions

The majority of the literature is grouped into Cluster I, that is, studies that employ a Likert-type instrument to measure unitary positions or belief dimensions. For the measurement of unitary positions, the Learning Environmental Preferences is commonly employed for which a composite score is derived that corresponds to positions (of the lower half) of the Perry scheme (Moore, 1989). For the measurement of belief dimensions, the bulk of Cluster I studies, nearly all employ Schommer's questionnaire (1990, 1998), a shortened version of it, a revised version of it, or an instrument inspired or guided by it. The original questionnaire consists of 63 short statements representing subsets of five hypothesized dimensions. Initially, a four-dimensional structure was recovered (Schommer, 1990): *Simple knowledge* (knowledge is simple rather than complex), *Certain knowledge* (knowledge is certain rather than tentative), *Innate ability* (the ability to learn is innate rather than acquired), and *Quick learning* (learning is quick or not at all).[5] The structure was subsequently replicated with other college students (Schommer, Crouse, & Rhodes, 1992) and, after slight modification to the instrument, with high school students as well (Schommer, 1993). However, the method of using subsets of items in the factor analyses by Schommer and colleagues (Schommer, 1990, 1993, 1998; Schommer et al., 1992) has been severely contested (e.g., Clarebout, Elen, Luyten, & Bamps, 2001; Hofer & Pintrich, 1997; Wood & Kardash, 2002). Many of the alternative instruments, such as Chan and Elliott's (2002) questionnaire, Epistemic Belief Inventory (Bendixen, Schraw, & Dunkle, 1998; Schraw, Bendixen, & Dunkle, 2002), Epistemological Beliefs Survey (Kardash, & Wood, 2002; Wood, & Kardash, 2002), or Jehng and colleagues' questionnaires (Jacobsen, Jehng, & Maouri, 1996; Jehng, Johnson, & Anderson, 1993), came about primarily because of evident difficulty using the Schommer questionnaire. These instruments, however, have suffered setbacks as well, such as low reliabilities, poor internal consistencies, retrieval of only a scant number of items per dimension, and so forth (see, for instance, Bendixen et al., 1998; Chan & Elliott, 2000; Debacker & Crowson, 2006; Debacker, Crowson, Beesley, Thoma, & Hestevold, 2008; Hofer, 2000; Kardash & Howell, 2000; Nussbaum & Bendixen, 2003; Wood & Kardash, 2002; Youn, 2000). Not surprisingly, researchers have had difficulty replicating dimensional structures, which is primarily attributed to questions of construct validity, methods of analysis, and lack of cultural sensitivity.

Most Cluster I investigations are domain general. Those studies that examined domain specificity (e.g., history vs. mathematic beliefs and psychology vs. science beliefs)

[5] As stated earlier, the inclusion of the latter two dimensions has been controversial because they pertain to learning rather than directly pertaining to knowledge or knowing (see Bendixen & Rule, 2004 or Hofer & Pintrich, 1997).

employed instruments modeled on or modified from the Schommer questionnaire. For example, the domain-general item “Scientist can ultimately get to the truth” (Schommer’s questionnaire) is altered for the Discipline-Focused Epistemological Beliefs Questionnaire (Hofer, 2000) to “Experts in this field [either psychology or science] can ultimately get to the truth.” Another highly utilized instrument, The Domain-Specific Belief Questionnaire (Buehl, Alexander, Murphy, 2002), is also inspired by the Schommer questionnaire.

2.4.1.2 Cluster II: Direct Questions About the Nature of Knowledge and Knowing

Studies in Cluster II pose rather open and direct questions about the nature of knowledge and knowing, often in the form of semi-structured interviews.

A number of studies based interview questions on Belenky et al.’s (1986) protocol (i.e., Berthelsen, Brownlee, & Boulton-Lewis, 2002; Bond et al., 2000; Bond & Burns, 2006; Brownlee, 2003, 2004; Brownlee et al., 2001; Burns & Bond, 2004; Jimmerson & Bond, 2001; Weinstock & Bond, 2000). The original interview schedule is composed of nine sections, requiring 2–5 h for participants to complete (Belenky et al.). Not surprisingly, researchers have attempted to distill out the more acutely epistemological aspects. These questions have tended to focus on knowledge, truth, experts, self as knower, and learning. Other interview protocols share a similar focus. For instance, Dirkx, Kielbaso, and Smith’s (2004) protocol pertains to participants’ thinking about knowledge and learning and Marra (2005) posed questions about the ideal college course, what it means to learn, definitions of knowledge and truth. In nearly every case, the coding of interview responses is guided by developmental models, such as women’s ways of knowing or the Perry scheme.

Three studies (Alexander, Murphy, & Guan, 1998; Alexander, Murphy, Guan, et al., 1998; Maggioni, Riconscente, & Alexander, 2006) utilize a paper-and-pencil instrument that asks participants to choose among graphic options depicting the relationship between knowledge and beliefs (designed by Alexander & Dochy, 1995). Participants are asked to explain and defend their choice in writing.

2.4.1.3 Cluster III: Measures of Judgments About Assertions

Cluster III is the second largest cluster; it includes studies that analyze participants’ evaluation and justification of (typically, competitive) assertions (i.e., what we refer to as epistemological judgments).

Much of this literature is firmly rooted in the RJM. The Reflective Judgment Interview (King & Kitchener, 1994) is used extensively. Participants make judgments about competing assertions that are distinguishable for being controversial issues “about which ‘reasonable people reasonably disagree’” [i.e., expert disputes] (King & Kitchener, 2004, p. 5). The original interview pertained to four issues: the safety of chemical additives in foods, the accuracy of news reporting, the creation of human beings, and the building of the Egyptian pyramids. Questions are posed, such as "How is it possible that experts in the field disagree about this subject," "… is it the case that one opinion is right and one is wrong," and "On what do you base that point of view," "Can you ever know for sure your position on this issue is correct" (King & Kitchener, 1994, p. 102).

A perusal of other utilized instruments reveals that the types of issues, probe questions, and response support can vary considerably. Some of the issues being reasoned might be regarded as widely controversial (e.g., "Should drugs be legalized" – Valanides & Angeli, 2005, p. 318), but others are certainly less so. For instance, Mansfield and Clinchy (2002) ask questions such as "Is that teacher nice or mean" or "Do those clouds mean rain" (p. 232). Beaudoin and Schonert-Reichl (2006) asked participants to judge competing claims about whether a driver's education course should be continued and Maclellan and Soden (2004) rate individuals' responses to the role of tutors and tutorials in gaining knowledge. Kuhn et al. (2000) consider items such as the correctness of preferences for music or spicy food and discrepancies in textbook explanations. These issues could equally be differentiated as expert, lay, or even childish. Finally, not all assertions involve competing ones. Hogan and Maglienti (2001) asked respondents simply to judge the validity of inferences.

Assessment tools employed are similar to the Reflective Judgment Interview when comparable probe questions are posed and minimal support is given in answering them (e.g., Beaudoin & Schonert-Reichl, 2006; Gottlieb, 2007, Mansfield & Clinchy, 2002; Valanides & Angeli, 2005; Weinstock, 2005; Weinstock & Cronin, 2003). Some studies employed instruments that pose fewer questions and provide support in the form of response options. For instance, the Epistemic Doubt Questionnaire (Hallett et al., 2002) presents participants with four response options representative of differing epistemological levels (e.g., "A careful analysis of what really happened will make the answer clear" – objectivist stance [p. 297]). Likewise, for Kuhn et al.'s (2000) instrument, participants need only choose and circle options regarding two questions: "Can only one of their views be right, or could both have some rightness" and "Could one view be better or more right than the other" (p. 316). Additionally, some utilized instrumentation is rather open or exploratory and does not include probe questions. For instance, Brem et al. (2001) simply asked students to evaluate internets sites of differing levels of credibility.

2.4.1.4 Cluster IV: Measures of Salient Meaning Making

Cluster IV interprets respondents' meaning making of issues of perceived significance, such as important decisions or significant academic or lifelong learning experiences. The approach is a traditional one; it can be traced back to the work of Perry (1970). The focus of the method rests on understanding knowing from the perspective of the knower. Specifically, participants explain in their own words how they interpret salient experiences or decisions and the impact this has on their thinking. The studies that we deemed representative of this approach asked respondents to describe: important learning experiences and their impact (Baxter Magolda, 2004; Pizzolato, 2003, 2004), how the loss of a loved one is experienced (Danforth & Glass, 2001), how one's most important decision was made (Pizzolato, 2005), challenging academic experiences (Pizzolato & Ozaki, 2007), and moral dilemmas during teaching and how they were dealt with (Tirri et al., 1999). Interviews were conducted in each study except one (i.e., Pizzolato, 2005).

2.4.1.5 Cluster V: Measures of Separate and Connected Knowing

Cluster V research concerns *Separate* and *Connected knowing*, typically referred to as spontaneously generated approaches to learning and knowledge (e.g., Galotti et al., 2006). The two approaches to knowing, as mentioned and briefly outlined above, were components of the women's ways of knowing model. Neither approach is considered more sophisticated, although there is a hint of favoritism toward the latter. The empirical basis for including the two styles, according to Clinchy (2002), was limited. Nevertheless, both forms have since received considerable attention.

All of the Cluster V studies employ Likert-type instruments, all but one the Attitudes Toward Thinking and Learning Survey designed by Galotti et al. (1999). The instrument asks participants to rate the degree to which they subscribe to each form. For example, "When I encounter people whose opinions seem alien to me, I make it a deliberate effort to 'extend' myself into that person, to try to see how they could have those opinions" (item for *Connected knowing*) or "I try to listen to other people's positions with a critical eye" (item for *Separate knowing*) (p. 754). The instrument, relies on purported behavior; nevertheless, some evidence of a correlation to actual behavior has been provided (Galotti et al., 2001) .

2.4.2 Methods of Measuring Epistemological Beliefs

While each cluster briefly outlines a type of instrument utilized by personal epistemological researchers, only the first four clusters are relevant to the assessment of epistemological beliefs. This is because Cluster V studies (i.e., those employing measures of *Separate* and *Connected knowing*) give scant reference to epistemological beliefs, suggesting their inference is not a focus. The other four clusters suggest somewhat different ways of measuring epistemological beliefs (see Fig. 2.1 below), each having notable shortcomings.

2.4.2.1 Inference from Related Beliefs

Cluster I instruments suggest that epistemological beliefs can be inferred from levels of agreement to related beliefs. By related beliefs, we mean that instrument

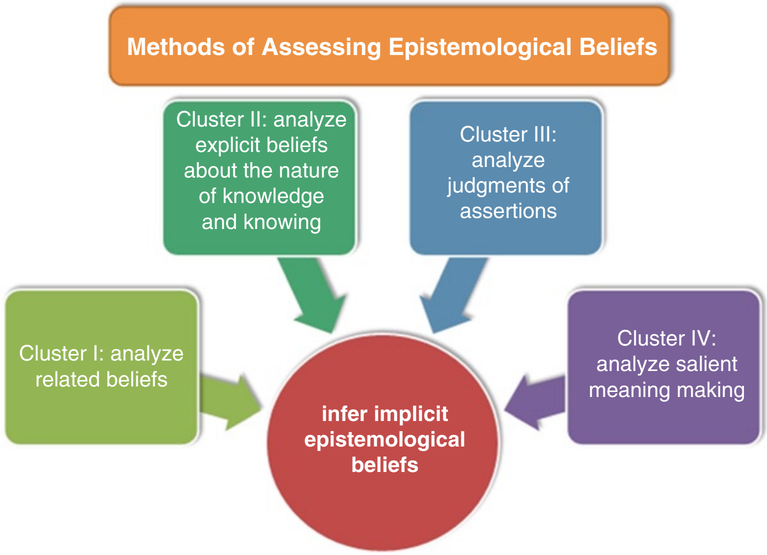

Fig. 2.1 Methods of assessing epistemological beliefs

items characteristically do not ask participants to endorse certain epistemological beliefs directly; instead, participants are asked to endorse theoretically associated beliefs. For instance, Schommer's questionnaire assesses the belief that knowledge is simple with the item "Most words have one clear meaning." Likewise, the Epistemic Belief Inventory measures the belief that knowledge is certain from the item "What is true today will be true tomorrow." Or, the Learning Environment Preferences measures positions of the Perry scheme with items such as "My ideal learning environment would emphasize basic facts and definitions" or "In my ideal learning environment, as a student I would study and memorize the subject matter – the teacher is there to teach it." The Epistemological Beliefs Survey assesses beliefs about the speed of knowledge acquisition with the item "You will just get confused if you try to integrate new ideas in a textbook with knowledge you already have about a topic." As such, the validity of Cluster I instruments hinges on their designers' ability to identify those items that accurately and adequately capture the underlying epistemological beliefs. Under Schommer's (1994) conceptualization that epistemological beliefs influence nearly all aspects of daily life, pinpointing relevant items would be challenging. This is precisely how Schommer-Aikins (2004) portrays the design of the highly influential Schommer questionnaire:

> In some sense this questionnaire was a means for researchers to explore minds in search of individuals' epistemological beliefs. How could one predict exactly the right items to present? With this dilemma to face, the questionnaire became a lengthy 63 items, and a wide array of items was administered as if casting a net of inquiry in order to catch a glimpse of individuals' beliefs. (p. 22)

Considering the overall low variance and other reported difficulties when surveys are employed, it is reasonable to wonder, as Maggioni et al. (2006) have, how successful or apt they are.

2.4.2.2 Directly Assessing Epistemological Beliefs

Cluster II suggests epistemological beliefs can be measured by posing open and direct questions to respondents. We presume less attention is given to this approach since it is normally accepted that laypeople do not have formal, well-organized conceptions of knowledge as a professional philosopher might (e.g., Hofer & Pintrich, 1997), nor would respondents [particularly younger ones] be readily able to articulate them in a meaningful way (e.g., Elen & Lowyck, 1999; Rosenberg et al., 2006). Nevertheless, the predominantly young adult participants in the studies reviewed were apparently able to respond to the direct questions posed. What do these responses reveal? Are they articulated summaries of the respondents' beliefs about knowledge and knowing or do they represent fragmented ideas, reproductions of philosophical arguments, reactions to the anticipated motives of the researcher, etc.? The word "knowledge" has more than one culturally accepted and promoted definition. Hence, it could be argued that participants are not sharing their own ideas abstracted from reflecting on their own mental creations, but instead are retelling what they have been told. It can also be argued that the method is still inferential. This in the sense that "cognitive researchers have long appreciated that there is more to one's knowledge than can be put into words or can be called to mind" (Buehl & Alexander, 2006, p. 31). While the researcher can directly assess explicit beliefs, she must still infer implicit ones. Researchers have found the accounts both meaningful and perplexing. For instance, the explicit epistemological beliefs measured were deemed influential to participants' educational expectations (Burns & Bond, 2004), perceptions of instructional practices (Hofer, 2004), class involvement (Burns & Bond, 2004), conceptions of child development (Bond & Burns, 2006), and child-rearing behavior (Jimmerson & Bond, 2001). Further, when thick descriptions are provided they can be of considerable significance to educators. For instance, Hofer (2004) vividly depicts how students' epistemological beliefs might affect how instructional practices are perceived and be influenced by those practices. Conversely, researchers note significant contradictions in respondents' reports. Brownlee et al. (2001) comment, "[t]here were some students who seemed to describe beliefs as if they emerged from two different people" (p. 261). Chan and Elliott (2002) make a similar remark. The inconsistencies reaffirm that lay accounts are not as well organized as professional epistemologists. It must be assumed that eliciting explicit epistemological beliefs is a delicate matter and that such accounts do not reveal everything that a person believes about the nature of knowledge and knowing.

2.4.2.3 Inference from Epistemological Judgments and Salient Meaning Making

Cluster III and IV suggest epistemological beliefs can be inferred from how a participant reasons specific issues. There are two concerns we should like to raise about this: (a) *what kind of issues and their reasoning are the most revealing of epistemological beliefs* and (b) *what level of generality can be assumed about them*. The consistent theme in Cluster III studies, is that the issues must trigger a sense of doubt, thus, requiring epistemological judgments. The epistemological judgments are theoretically regulated by higher-order thinking, which is, in turn, dependent upon certain epistemological beliefs. This was originally proposed by King and Kitchener (see King & Kitchener, 1994, 2004; Kitchener, 1983). The consistent message in Cluster IV studies is that the issues must be of personal relevance. The only articulation of why this might be is from the earlier work of Perry (1970). When students are asked, "Would you like to say what stands out for you during this year," "'[s]tands out' does imply a structure, that of salience, or figure against ground" (Perry, 1970, p. 19). The flexibility of his open interviews was perceived crucial to revealing precisely how the respondent (i.e., figure) accomplishes his bearing (i.e., grounding) in the world. Under this proposal, epistemological beliefs structure meaning making about matters of uncertainty and salience and, thus, ground the individual when he is disturbed by them. If a student, for example, is sorely underachieving in a certain academic course, she may seek a tutor who *knows the answers* and can prescribe them efficiently. From this, Perry might infer the student believes that there is certain, correct knowledge privy to only those in the know. There are, of course, strands of similarities between Perry's theory and that proposed by King and Kitchener. Both suggest that the reasoning of perplexing issues will be framed by certain epistemological beliefs. Nevertheless, the variety of issues and reasoning about them operationalized in Clusters III and IV, raises the question of whether some reasoning of certain problems evoke epistemological beliefs, while certain reasoning of other issues do not, or not as much.

Another issue with these methods is deciding the generality of the epistemological beliefs. Due to the open nature of Cluster IV instrumentation, the salient meaning making observed must consist of a wide variety; the researcher is obligated to determine patterns among them and then infer the epistemological beliefs based on this (see Baxter Magolda, 2004). These studies always infer a domain-general range. Cluster III instruments can include issues that traverse a host of judgment domains and participants' reasoning performance can also vary, the researcher determines the average or typical performance. For instance, the Reflective Judgment Interview is composed of issues from four domains (i.e., science, current events, religion, and history); participants are positioned according to the level that represents "the most commonly used set of assumptions" (King, Kitchener, & Wood, 1994, p. 140). Studies that examine domain specificity examine average performance *within* particular domains, and then infer the domain-specific epistemological beliefs. Hence, in one study, an instrument can be used for domain-general purposes (e.g., Kuhn & Park, 2005), while in another study, the same instrument can be used for domain-specific purposes (e.g., Kuhn et al., 2000). On a context level, Rosenberg et al. (2006) observed contextual variations in the reasoning of causal explanations and then inferred fine-grained, context-sensitive epistemological beliefs. In each case, the researcher theoretically decides the generality; the inferences differ only according to how the observed variability is understood.

2.4.3 Argument Concerning the Measurement of Epistemological Beliefs

One of the fundamental problems with epistemological beliefs research is that it is difficult to conclusively know whether various measures are equally effective at accessing the same construct or even if they are accessing the same construct. Because epistemological beliefs are normally regarded to be implicit, inferential methods are requisite and must depend on accurately interpreting the visible manifestations of the underlying cognitive structures. The cluster review demonstrates that there are at least four unique ways that researchers access epistemological beliefs and less substantial deviations once within-cluster variations are considered. Hence, it should come as little surprise that there are confounding results between researches (see, for example, Chandler, Hallett, and Sokol, 2002). To move beyond this state of affairs, there is an urgent need to consider what constitutes a suitable inference. We believe this directs future research in two ways:

Foremost, inferences about participants' epistemological beliefs should be garnered from more than one vantage. Of all the studies reviewed, only 17 employ more than one instrument. Of these, only three draw on different instrumentation types to triangulate interpretations. Would it not be possible to bring several distinct approaches together to augment inferences? This implies generating theory about distinctive ways epistemological beliefs are manifested and then synchronizing them in instrumentation to support inferences. Pajares (1992) summarized the measurement of beliefs as something "that can only be inferred from *what people say*, *intend*, and *do* [italics added]" (p. 316). While the vantages he suggests may not be identical to the ways epistemological belief researchers believe epistemological beliefs are manifested, his basic argument is noteworthy: inferences should be bound by more than one type of expression. Doing so may alleviate the question of whether empirical differences are measurement related.

Lastly, not only should combining approaches be considered, but novel methods should also be sought. It is safe to say no perfect measure does or will exist. Which means future research efforts benefits from actively pursuing other "creative and effective ways to bring individuals' knowledge to the surface and to allow thoughts or understandings to be shared in natural and meaningful ways" (Buehl & Alexander, 2006, p. 31). Some efforts have been put forth. For instance, the Connotative Aspects of Epistemological Beliefs (Stahl & Bromme, 2007; Stahl, Pieschl, & Bromme, 2006) asks respondents to rate 24 pairs of opposing adjectives (e.g., simple vs. complex, temporary vs. everlasting, and structure vs. unstructured) when thinking about a particular domain of knowledge.[6] Although around for some time, the previously mentioned instrument designed by Alexander and Dochy (1995) that asks participants to choose among graphic depictions of the relationship between beliefs and knowledge remains a unique way of having participants think explicitly about the concepts and then explain their relations. Briell et al. (2010) ask their participants simply to draw knowledge and then explain the drawing. These and other explorations are undoubtedly consequential steps toward the betterment our inferences of this complex construct.

2.5 Conclusions

We have attempted to make the breadth of nomenclature, conceptualizations, and instrumentation of personal epistemology manageable that it might benefit the reader interested in understanding relations to cognitive flexibility. However, the reader must also grapple with the fact that cognitive flexibility is subject to multiple meanings. To conclude this chapter, we will briefly explain how the two constructs may relate by using a point of reference that is almost certainly familiar to the reader.

Cognitive Flexibility Theory (CFT) is a general theory of learning, instruction, and knowledge representation endorsed by Spiro and colleagues (e.g., Jacobsen & Spiro, 1995; Spiro, Feltovich, & Coulson, 1996; Spiro & Jehng; 1990). Spiro and Jehng (1990) define cognitive flexibility as "the ability to spontaneously restructure one's knowledge, in many ways, in adaptive response to radically changing situational demands (both within and across knowledge application situations)" (p. 165). In practical terms, it concerns the apprehension of abstract knowledge (i.e., patterns, themes, principles) from a collection of thematically related scenarios/perspectives and the subsequent application of that learning to other related contexts. The envisioned construct is reserved to "ill-structured domains"[7] (Spiro & Jehng, 1990), instances for which a collision of multiple issues are involved (e.g., the personal, legal, financial, social, and ethical issues implicated in the storing of personal information in massive computer databases). Additionally, it can be taught, to the extent that the cognitively flexible individual does it routinely.

[6]Because the authors contend this is an indirect measure of epistemological beliefs via evaluative-associative assumptions, it did not fit into our cluster scheme. If viewed as a direct measure of epistemological belief dimensions, we would have regarded it as a novel Cluster II instrument.

[7]It should be noted that "ill-structured" is used differently by Spiro and colleagues than it is with the RJM. Ill-structured problems according to the RJM are problems "about which 'reasonable people reasonably disagree'" (King & Kitchener, 2004, p. 5). Specifically, they are problems in which the necessary elements for resolving them are either unknowable or unknown, there is no single correct procedure, and "there is not a single unequivocal solution which can be effectively determined at the present moment" (Kitchener, 1983, p. 224).

Relations between cognitive flexibility and personal epistemology depend on whether epistemological beliefs or epistemological judgments are considered:

Spiro and colleagues have considered the relationship to epistemological beliefs, which is evident in a couple of their instruments (i.e., Epistemic Beliefs and Preferences Instrument (Jacobson & Spiro, 1995), Cognitive Flexibility Inventory (see Spiro et al., 1996)). While both instruments are said to measure beliefs about the nature of knowledge and learning, it is unsaid precisely what those beliefs are. It is said the beliefs demonstrate an embracing or shunning of complexity. If this is a good reference, then there needs to be theoretical efforts put forth about what specific epistemological beliefs would reveal this and why – so they can then be tested.

Relations between epistemological judgments and cognitive flexibility can be viewed from two vantages. The first is simply that those who are apt to make certain epistemological judgments may be more or less apt to think with cognitive flexibility. The challenge here is to develop theory that explains in detail why this may occur and then test it. The second way of looking at a relationship is that the two constructs may overlap, since cognitive flexibility is a distinct form of learning and epistemological judgments are an important aspect of learning. However, the magnitude of their overlap would depend on the perception of the researcher. The only epistemological judgment that is obvious according to CFT is the need for the student to decide what constitutes a justified assertion when making one. After a student has read multiple perspectives concerning an ill-structured domain, she then applies the abstract knowledge acquired in making assertions regarding a related scenario. To do so, she invariably must make judgments about the coherency and sufficiency of her own opinions. CFT does not mention that she should also evaluate the trustworthiness of opinions rendered in the learning scenarios. This is probably because CFT presumes the learning material is reputable, and that the student should be confronted with and accepting of plurality. However, other researchers may contend that real-world learning situations consist of diverse and competitive opinions that are not always or equally trustworthy. From this standpoint, the researcher may consider a student's evaluation of assertions presented in the material to be consequential to the depth and integrity of her acquired understandings. If so, the researcher may choose to redefine cognitive flexibility with the insistence that such epistemological judgments are an integral part of it.

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Chapter 3
The Generative Nature of Epistemological Judgments: Focusing on Interactions Instead of Elements to Understand the Relationship Between Epistemological Beliefs and Cognitive Flexibility

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3.1 The Relationship Between Epistemological Beliefs and Cognitive Flexibility

In the last 15 years, research on epistemological beliefs has provided ample evidence that the construct is an important variable in learning processes. The construct is acknowledged by a growing number of researchers and discussed as a predictor as well as an outcome of learning processes. Adequate epistemological beliefs are defined as an important learning goal to develop an elaborated understanding of scientific findings. Bromme and Kienhues (2008) considered epistemological beliefs as an intuitive philosophy of science. Such understanding of the nature of scientific knowledge is necessary for active civic participation in modern science- and technology-based societies (Bromme, 2005). Therefore, epistemological beliefs can be seen as a prerequisite to successfully complete higher education.

On the other hand, a variety of conceptual and methodological issues still exist. As a result, the clarification of these issues has become essential for future research. One important issue is related to the stability of epistemological beliefs: Learners appear to have (a) general and relative stable beliefs about the nature of knowledge; (b) more or less stable beliefs about different scientific disciplines; and (c) concurrently context-dependent[1] and, therefore, variable beliefs. Such issues about the levels and the stability of the beliefs are highly relevant on a conceptual as well as on a methodological level.

[1] "Context" is a complex notion. In this chapter, context is defined by the specific scientific content that a learner has to elaborate within a specific learning scenario like a school lesson, a seminar, or an informal learning setting. Thus, context is always seen in relation to a specific scientific content that has to be dealt with within a learning scenario.

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The aim of this chapter is to discuss the issue of stability and flexibility of learner's applied beliefs in relation to the construct of "cognitive flexibility." In this chapter, arguments are presented that learner's ability to make appropriate epistemological judgments might depend on comparable cognitive mechanisms that are described in the construct of "cognitive flexibility."

3.1.1 Preliminary Remarks

Before these assumptions are explained in more detail, two points have to be emphasized in advance. First, in this chapter the term *epistemological beliefs* is defined as learners' beliefs about the nature of knowledge and knowing (Hofer, 2000) and the beliefs are perceived in relation to scientific information. In most learning scenarios, learners first encounter scientific information from different disciplines that is conveyed through teachers or the media, such as textbooks. Thus, when learners judge such kinds of knowledge claims, they refer to their epistemological beliefs about the nature, source, and justification of scientific knowledge.

One of the reasons for apparently paradox results in research on epistemological beliefs might result from insufficient differentiation of the different kinds of "knowledge" that have to be judged by subjects. For example, Kuhn and Weinstock (2002) presented participants with scenarios about taste, values, and aesthetics such as "Robin thinks lying is wrong/Chris thinks lying is permissible in certain situations." King and Kitchener (1994) used ill-structured problems like "some people believe that news stories represent unbiased, objective reporting of news events. Others say there is no such thing as unbiased, objective reporting and even in reporting the facts, the news reports protect their own interpretation into what they write (Kitchener, 1986, p. 80)."

More direct knowledge claims are scientific statements like "water is boiling at 100°C" or scientific claims like "endurance sports reduce the risk of heart diseases." No empirical evidence supports the likelihood that such a broad variety of different kinds of "knowledge" are all judged in the same way. Do subjects activate the same epistemological beliefs to judge a scientific statement as with a statement about personal taste? As long as this issue is unanswered, the term *epistemological* should clarify that the scenarios examined by learners are learning scenarios that include contents of scientific disciplines that learners must process.

Second, in this chapter, epistemological beliefs are differentiated from epistemological judgments. *Epistemological beliefs* are assumed to exist on a general and on discipline-related levels and can be seen as relatively stable, changing mostly during processes of (formal) education. *Epistemological judgments* are defined as learners' judgments of knowledge claims in relation to their beliefs about the nature of knowledge and knowing. They are generated in dependency of specific scientific information that is judged within a specific learning context. As explained below, an epistemological judgment might be a result of the activation of different cognitive elements (like epistemological beliefs, prior knowledge within the discipline, methodological knowledge, and ontological assumptions) that are combined by a learner to make the judgment. Epistemological judgments are seen as context dependent and flexible. In most studies, the applied methods are able to examine epistemological judgments but not the epistemological beliefs as such.

To discuss the idea of epistemological judgments in relation to the flexibility of the cognitive system, the term "cognitive flexibility" must be first introduced from different theoretical perspectives.

3.1.2 Cognitive Flexibility and the Cognitive Flexibility Theory

In educational psychology, the construct of "cognitive flexibility" is usually associated with the Cognitive Flexibility Theory. (Jacobson & Spiro, 1995; Spiro, Feltovich, Jacobson, & Coulson, 1991). Spiro and his colleagues have investigated how knowledge about a complex ("ill-structured") content domain can be acquired in a way that ensures its flexible use. The goal is to stimulate learning transfer and to avoid "inert knowledge," that is, knowledge a learner can reproduce but fails to apply in new situations (Bereiter & Scardamalia, 1987). Cognitive flexibility refers to this transfer of knowledge and is defined correspondingly as the ability to structure one's own knowledge in a variety of ways in adaptation to changing situational demands (Spiro & Jehng, 1990). To apply knowledge to a new situation, a learner has to assemble relevant conceptual and case-specific knowledge components. The importance of cognitive flexibility is illustrated in relation to the philosopher Ludwig Wittgenstein (1889–1951) who shaped the metaphor of the crisscross landscape, a landscape that someone can only fully understand by exploring it in a way that considers multiple paths presenting the same landscape from different perspectives (Jacobson & Spiro, 1995). The Cognitive Flexibility Theory relates to learning scenarios with the aim to foster knowledge transfer, in an ill-structured domain for advanced learners (Jacobson & Spiro, 1995; Spiro & Jehng, 1990). The reference to advanced learners is controversial in the literature. For example, Feltovich, Spiro, and Coulson (1989) argue that novices have to understand the concepts and relations within a discipline and that the introduction of complexity in early stages of learning might be too confusing. Researchers like Duffy and Knuth (1990) argue that the basis for dealing with complexity must be integrated into the early learning processes and that it is not useful to restrict transfer learning to advanced learners.

Nevertheless, with the focus on knowledge transfer in ill-structured domains for advanced learners, one might infer that cognitive flexibility seems to be an "exceptional case," a level that can only be reached by advanced learners in advanced learning scenarios related to a specific set of learning tasks. Therefore, cognitive flexibility might be seen as less important in most learning scenarios that ostensibly appear not to be related to the acquisition of "transfer knowledge." As a result, teachers and researchers might focus on elements and methods that are more useful to foster cognitive stability than flexibility in a broad range of learning scenarios. Furthermore, conducting research with the focus and intervention on the more stable parts of cognitions appears to be more manageable.

On the other hand, such a view could be problematic when cognitive flexibility is examined from a different perspective: The cognitive processes during learning are related to the whole human information processing system. Therefore, on an abstract level, cognitive flexibility has to be related to our whole cognitive system. Examining the flexibility of our cognitive system from the perspective of other disciplines like physiology or neurosciences could provide fruitful hypotheses. These disciplines provide ample evidence and present models showing that the human information processing system is highly flexible and able to work in interaction with the demands of continuously changing contexts. From such a perspective, cognitive flexibility can arguably be discussed as the norm, not the exception.

3.1.2.1 Statement I: Cognitive Flexibility Is Normality Not an Exceptional Case

In research on the human information processing system, flexibility appears to be a prerequisite for processing the diversity of ever-changing inputs from the environment and from the system itself: Uncertainty is the norm for the sensory systems and the motor functions, as these systems process continuously changing environments. This claim can be explained using the visual system as an example. The visual world is viewed under variable and constantly changing conditions. Nevertheless, we are able to identify objects, such as a piece of coal in sunshine as well as in the dark, even though the intensity of the light, the reflectivity, and the shading are different in a physical measurement. Thus, one form of uncertainty that the visual system has to process, in this case context, is related to continuously changing lighting conditions.

Another form of uncertainty is given by the anatomy of the eyes: Light passes through the various anatomical structures of the eye and through different types of optic nerves before it reaches retinal photoreceptors. As a result of these and other anatomical and physiological characteristics, a part of our visual perceptions is constructed within the visual system and not a result of a stimuli input on the photoreceptors (cf., Grossberg, 1987a). To accomplish the impression of a "stable" vision, processes of construction, adaptation, and the ability to deal with flexible contextual demands are necessities of sensory information processing. They are normal and not the exceptional case.

One theory of visual perception apropos of this perspective was published in 1987 by Stephan Grossberg. He included issues of uncertainty and flexibility as central elements of his theory (cf., Grossberg 1987a, 1987b). Grossberg, a cognitive scientist, focuses on how cognitive mechanisms are organized (e.g., in vision, learning processes, and language comprehension) to enable human beings (and machines) to adapt (spontaneously) to contextual changes in the environment. In his view, models using step-by-step processing and a progressive reduction of complexity fail to explain how the growing affordances of processing during information processing can be dealt with.

Without going into detail, Grossberg developed a visual perception model with heterarchical processing systems that *continuously* interact with each other. The visual system is able to adapt to changing contextual demands by parallel and interacting processes that enables it to be fuzzy during information processing. In this view, flexibility of the cognitive system depends on continuous interactions, reinterpretations, “intended” uncertainties, and constructions that are made in continuous interaction with the given contexts. Grossberg has reinterpreted existing empirical findings from his theoretical view and was able to provide more coherent conclusions. He claimed that the relevant computational unit for research to understand a system cannot be a single processing unit. Instead, modeling the interactions between complementary units in changing contexts is seen as relevant to understanding how complex information about a changing world is computed.

From this perspective, flexibility of the cognitive system is seen as a highly important aspect of the cognitive system necessary to deal with changing contextual demands. Learning processes are part of the human information processing system. Therefore, processes enabling flexibility of the cognitive system as described above can be assumed to use comparable mechanisms as processes that enable cognitive flexibility in learning processes – at least to some degree.

3.1.3 The Mechanism of Cognitive Flexibility and Epistemological Beliefs: First Conclusions

If the analogy sketched above is acceptable, then using the basic ideas of Grossberg’s theory and his research methods as heuristics might be helpful when investigating the mechanism of cognitive flexibility in relation to learners’ epistemological beliefs and their epistemological judgments.

Two short examples should provide an initial insight how this can be accomplished. In research on epistemological beliefs, the use of questionnaires to measure epistemological beliefs is common. The classic Epistemological Questionnaire (EQ) was developed by Schommer-Aikins (Schommer, 1990). However, the factor structure supposed in Schommer-Aikins’s pioneering work did not prove to be stable – it could not be replicated in other studies (e.g., Chan & Elliott, 2002; Clarebout, Elen, Luythen, & Bamps, 2001; Elby, Frederiksen, Schwarz, & White, 2003; Hofer, 2000; Schraw, Bendixen, & Dunkle, 2002).

These and other kinds of criticisms about the validity and reliability caused the development of numerous follow-up questionnaires, which were deeply inspired by Schommer-Aikins’s EQ. As a result, a broad variety of questionnaires exist: the DBSQ (Buehl, Alexander, & Murphy, 2002), the DEBQ (Hofer, 2000), the Epistemological Beliefs Instrument (Jehng, Johnson, & Anderson, 1993), and the Epistemological Beliefs Inventory (Schraw et al., 2002) – to list just a few. Notwithstanding, all attempts to date to develop a questionnaire with strong reliability and validity have brought little success. The main problem is seen in the unstable factor structure of the instruments. Another problematic aspect concerns the items which are often indirectly related to epistemological beliefs.

From the perspective of cognitive flexibility as presented above, understanding the results in more detail might shed more light on the nature of epistemological judgments, instead of focusing on statistical values like Chronbach's alpha and searching for the stable factor structures. The notion is plausible that different learners use different argumentations to justify their judgments and that such argumentation can change between different contexts. For example, the statement "It is annoying to listen to a lecturer who cannot seem to make up his mind as to what he really believes" (from the EQ, Schommer, 1990) might be answered in a general way ("usually I agree") or in relation to the specific discipline, topic, task, teacher, or classroom. Furthermore, students might relate this issue to their epistemological beliefs about the certainty or simplicity of knowledge, but it is also possible that they think about a specific teacher who is not able to present a clear point of view, or that they use a mixture of associations. Thus, the cognitive elements that are activated to make a judgment might differ (i.e., epistemological beliefs versus an estimation of characteristics of a teacher) and might change according to the context. From the perspective of cognitive flexibility presented above, such interactions of different cognitive elements could be expected. Deeper analyses of learners' arguments as to why they are given a rating and of the stability of the ratings and the arguments over different situations might not only help to understand more about the instrument but also about the construct "epistemological beliefs" itself. For example, are learners activating their epistemological beliefs separately or in interaction with other cognitive elements? Are the activated epistemological beliefs general, discipline related, or even topic related? Do learners use different arguments for an item when the learning context changes? Analyses like this would help to understand whether the problems of *nearly all* instruments in the research field should be attributed to the instruments' psychometric properties or whether it should be viewed as a sign that some aspects of the construct "epistemological beliefs" need to be reexamined.

A second example concerns the development of epistemological beliefs (e.g., King & Kitchener, 1994; Kuhn & Weinstock, 2002). Development of epistemological beliefs is often described as stagelike from a dualistic, absolute view on knowledge to an evaluative perspective. Each stage is characterized by a specific way of thinking and learners can be assigned, more or less, to their present attained stage. Chandler, Hallett, and Sokol (2002) criticized that all assumed stages of such models can be found in all age levels. They questioned how such results might be possible and whether there is no progress in development.

One explanation why such results are possible is that the strict sequence of the developmental stages can be doubted (Tabak & Weinstock, 2008). Variance between persons and contexts appears to be larger than the assumptions of a stage model are able to explain (Hofer, 2009). Another explanation might be that the ratings given in different age levels might be the same (e.g., an absolutistic view), but that the argumentation structures and the cognitive elements that different learners activate to reach the judgment might be greatly different from each other. An epistemological judgment of a student in elementary school that led to the categorization as absolutivism should differ substantially compared to an epistemological judgment of a university student in the same category. Understanding the apparently paradoxical results in detail requires looking beyond the ratings. The interaction between the cognitive elements of the students must be examined to understand, if and how they use them in their argumentation and how an epistemological judgment results.

As the examples illustrate, examining some of the unsolved issues in research would be relatively easy to begin by integrating more process data and deeper levels of analysis of the context. Furthermore, the examples present first evidence of justifying the necessity to differentiate between epistemological beliefs and epistemological judgments.

In research on epistemological beliefs, the main focus is, nevertheless, not on the context or flexibility but on the idea of stability over flexibility. This is consistent with the research philosophy in educational psychology.

3.1.3.1 Statement II: Stability Is Normality in Educational Psychology and Cognitive Flexibility Is the Exceptional Case

In educational psychology, the view on flexibility of the cognitive system has changed during the last decades. Despite the progress, in theories about learning processes and knowledge acquisition, cognitive flexibility is mostly viewed from one perspective: to be something special, an aim that is hard to reach. An important reason for this could be that compared to the research fields of neural sciences presented above, the level of research is different. Conducting research about adapting patterns of neural activities seems to be at a more fine-grained level than understanding learning processes in ill-structured problem cases. Flexibility on neural levels with different patterns of excitatory and inhibitory cells might not be comparable to cognitive flexibility defined in the sense of knowledge transfer to new situations. Nevertheless, each cognitive process is related to neural mechanisms and cannot be grounded in completely different mechanisms. For example, Grossberg also developed concrete theories about learning processes (Carpenter & Grossberg, 2002) using his ideas of a fuzzy logic presented above. Another argument is more pragmatic: when unsolved issues exist on a level of research and cannot be explained on this level, integrating deeper levels might be more useful, that is, more fine-grained levels and other perspectives as well to search for an explanation.

Researchers in the field of educational psychology are focusing on elements that emphasize linearity of processing, certainty, and stability; even when ample examples of theoretical assumptions and models can be found that changed from more stable views to more connectionist assumptions allowing for greater flexibility. Four examples follow to illustrate the shift in theoretical assumptions:

– The ideas of schemata (Bartlett, 1932; Schank, 1972) and scripts (Schank & Abelson, 1977) are attractive and commonly used to describe complex knowledge organizations. These constructs, however, present a classical example for a shift in theoretical assumptions that is often ignored in the literature. The authors modified their model to account for higher flexibility and adaptivity to situational demands. Rumelhart, Smolensky, McClelland, and Hinton (1986) explained schemata with a connectionist idea. Schemata emerge in the moment when they are activated from patterns of interconnected elements. Thus, schemata are not explicitly stored in memory but are constructed by processes of activation and inhibitions of smaller units. Schank (1982) introduced the idea of MOPs (memory organization packets), which are hierarchically ordered memory packets of different levels of abstraction that interact with each other and can be combined to form scripts. The advantage is that each MOP (e.g., the MOP how to pay) can be activated in different contexts (e.g., paying in a restaurant and paying at the coiffeur). The main advantage is that stable and inflexible general units, such as whole scripts, are reduced to ensembles of smaller, more interwoven units, allowing higher flexibility in different contexts.

– Barsalou (1987) challenged the view that representations of concepts are relatively static. He provided empirical and theoretical evidence that concepts (and also the structure of categories and categories as such) are unstable and that they change as a function of the context. For example, "duck" would be associated with different characteristics in the context of a walk around a pond or a visit at a Chinese restaurant. Whenever a concept is activated, however, there is also some context-independent information that is automatically activated as well (e.g., that a "duck" is an animal). Thus, the actual meaning of a concept can be seen as a mixture of context-independent and of context-related characteristics. Barsalou argued that this cognitive mechanism allows for greater flexibility of the cognitive system.
– Kintsch (1998) included ideas advanced by Barsalou (1987) into his construction–integration (CI) model of text comprehension. He argues that knowledge is represented in the form of a network of propositions. This network with its existing propositions and the connections between the propositions defines the whole information that can be activated at all. But only parts of this network are activated within a concrete context (e.g., reading a specific text in a classroom). This is performed in a process of "constraint satisfaction." This suggests that a context inflicts semantic constraints. These allow for inhibition of propositions that seem incorrect in the context and activation of those propositions that represent an adequate meaning. Important for flexible and adequate activation of knowledge is that (a) learners have a detailed and comprehensive knowledge structure, and (b) they are able to interpret the demands and constraints of a given context.
– Research on self-regulation emphasizes the complex interactions between different cognitive processes and elements that have to be considered to understand how learners in a specific situation are performing their task. For example, the COPES model of Winne and Hadwin (1998) describes how parallel and heterarchical processes in different subsystems contribute to the aim of completing a task.

All of these examples represent modifications of theoretical models that were introduced to take the flexibility and context dependency of our cognitive system into account. Such modifications and the emphasis of contextual adaptation can be found in other theoretical perspectives and research fields as well. They present theoretical and empirical data supporting the ability of our cognitive system to react flexibly to changing contextual demands. Thus, demands of specific situations, uncertainties, and flexibility are taken seriously in educational research. However, in empirical research and theoretical modeling, stable solutions that might simplify reality are still preferred.

3.1.4 Flexibility of Epistemological Beliefs

In the early stages of research on epistemological beliefs, most researchers have also conceived this construct as general and rather stable ways of thinking about knowing and knowledge, developing from sometimes called “naïve” toward sophisticated epistemologies.

Presently, a growing body of empirical evidence suggests that epistemological beliefs may be less coherent, more discipline related (e.g., Bromme, 2005; Buehl & Alexander, 2001; Buehl et al., 2002; Limon, 2006) and more context dependent than it was assumed at the beginning of research on epistemological beliefs (Buehl & Alexander, 2006; Elby & Hammer, 2001; Hammer & Elby, 2002; Hofer, 2006; Pintrich, 2002).

Epistemological beliefs are discussed in relation to specific learning contexts and the contents to be judged. Flexibility and contextualization are reflected in terms, such as “epistemological beliefs in context” (Mason & Boldrin, 2008; Mason & Boscolo, 2004), “epistemological understanding” (Kuhn, Cheney, & Weinstock, 2000), “epistemological resources” (Hammer & Elby, 2002), and “the generative nature of epistemological beliefs” (Bromme, Kienhues, & Stahl, 2008).

3.1.5 Epistemological Resources: The Perspective of Hammer and Elby

David Hammer and his colleagues notably describe the influence of context as an important aspect of their theory (cf., Elby & Hammer, 2001, 2010; Hammer, 1994; Hammer & Elby, 2002, 2003; Louca, Elby, Hammer, & Kagey, 2004; Rosenberg, Hammer, & Phelan, 2006; Scherr & Hammer 2009). Elby and Hammer (2001) published a challenging critique on the definition of sophisticated epistemological beliefs as it is defined by most researchers in this field. They presented elaborative examples that beliefs about the tentative, relativistic, and complex nature of knowledge are neither productive nor correct in many learning situations. Hammer and colleagues argued that existing models would result in the presumption of overly stable epistemologies that could not account for the context dependency found in empirical studies. It is important to note that the criticized researchers do not believe that learners have only one stable belief that is activated in all situations. Schommer-Aikins (e.g., Schommer, Calvert, Giana, & Bajaj, 1997), for example, defined individual beliefs as frequency distributions. Thus, each learner assumes a certain percentage of knowledge to be tentative, a certain percentage to be unchanging, etc. This would allow a learner to be able to judge knowledge, for example, to be more or less certain or uncertain in different situations. Schommer-Aikins, however, assumed that there is a peak in the frequency distribution – a predominant belief that is activated spontaneously and in most learning situations.

Hammer and his colleagues present the concept of epistemological resources. Hammer and Elby (2002) described four categories of epistemological resources: (a) resources to understand the nature and sources of knowledge, (b) resources to understand epistemological activities, (c) resources to understand epistemological forms, and (d) resources to understand epistemological stances. Each category is further differentiated. For example, in their first category, they distinguish resources, such as "knowledge as propagated stuff," "knowledge as free creations," "knowledge as fabricated stuff," "knowledge as inherent," and "knowledge as direct perception." The authors emphasize that the resources they describe should not be viewed as fully established. They rather intended to demonstrate the kinds of resources that might be involved and that future research might reveal more differentiated and other resources. Nevertheless, since 2002, the same resources are described in their articles without further differentiations. From this theory, people have different resources that they can activate to understand knowledge (Louca et al., 2004). Depending on the context, the activated resources are more or less appropriate. Thus, instead of trying to change epistemological beliefs, the authors suggest that teachers should help students to find productive resources in relation to the learning context.

The theory has two important implications: Context and flexibility have to be taken seriously, and as a consequence, questionnaires do not provide sufficient information to understand epistemological beliefs. Instead, interviews and observations of learners in different contexts are apparently more productive.

However, the notion of described resources can be criticized as not being concrete enough to understand and to predict how learners develop an epistemological judgment in a specific situation. To provide an example, Louca et al. (2004) described that a 6-year-old child uses the "knowledge as transmitted stuff" resource when her daddy tells what is for dinner.[2] In another situation, when asked how she knows that her mommy brought her a present, she uses the "knowledge as fabricated stuff" resource, because she figured it out on her own. One problem with these examples is that the authors do not differentiate between information and knowledge. This lack of distinction could be problematic in relation to the productivity of the resources. The following four situations explain why

– The 6-year-old Lisa sees her daddy leaving the kitchen. He has a cooking spoon in his hand and tells her: "Today we have roast for dinner" (and she knows that he cooked it himself)

[2] The examples are not related to scientific knowledge, but they are appropriate to illustrate the critique.

– The 6-year-old Lisa sees her daddy coming home from work, entering the living room where she is, sniffing and then telling her: "Today we have roast for dinner" (and she remembers that he never made a right prognosis with such sniffing attempts during the last year)
– A stranger on the street tells Lisa: "Today you will have roast for dinner." (and she is confused: how should he know?)
– Lisa has a birthday. Her daddy is leaving the kitchen with a cooking spoon. He smiles, blinks his eyes at her, and says: "Today we have spinach for dinner," – a dish that she really hates (and she assumes that he is lying to surprise her with one of her favorite meals)

According to Hammer and his colleagues, the "knowledge as transmitted stuff" resource should be activated in all of the described situations, but it is not helpful for Lisa in any of the scenarios to judge whether she can believe her daddy. Also, a combination with other resources like the "knowledge as fabricated stuff" resource is not helpful for the judgment. The problematic point from an epistemological view is that information – not knowledge – is transmitted to her, and that Lisa has to make an epistemological judgment about the "truth" of the information. The epistemological resources described by Hammer and his colleagues appear not to be sufficient to accomplish this.

This claim can be substantiated with another example: Hammer and his colleagues describe resources to understand epistemological forms. One of the resources in this category is related to facts. Consider Lisa talking to her older brother who says, "The earth is round. That is a fact." Her father tells her, "Leuven is a city in the Netherlands. That is a fact," and her younger girlfriend tells her, "It is a fact that elves exist." The resource to define what a fact is and the resource "knowledge as transmitted stuff" and the resource "knowledge as fabricated stuff" would not help to make the epistemological judgment if each of the claimed facts is really true.

The idea of resources is encouraging because of the strong focus on contextualization and flexibility. Although, it is not elaborated in enough detail to understand how an epistemological judgment about a specific "knowledge claim" is generated. Furthermore, Hammer and his colleagues define epistemological beliefs in a broad sense including beliefs about learning and activities like discussion. Which aspects of (epistemological) beliefs the authors focus on in their descriptions is not always clear.

3.1.6 The Generative Nature of Epistemological Judgments

Another theoretical assumption about the context dependency of epistemological beliefs is made by Bromme et al. (2008) and Stahl (2009) who described the idea of a generative nature of epistemological judgments. Their idea was inspired by the assumptions about the flexibility of the cognitive system presented above and by

Spiro and Jehng's (1990) definition of cognitive flexibility as the ability of our cognitive system to structure one's own knowledge in a variety of ways in adaptation to changing situational demands. They further referred to Buehl and Alexander (2006) who defined epistemological beliefs as complex, multidimensional, multilayered, and interactive. Buehl and Alexander argued that many knowledge characteristics and characteristics of beliefs about knowledge should be seen as comparable because of influences between knowledge acquisition and the forming of epistemological beliefs. Thus, if knowledge has to be defined as complex, multidimensional, multilayered, and interactive, then there is no reason to assume that a construct like "epistemological beliefs" should be seen as more simple.

Bromme et al. (2008) and Stahl (2009) discussed the creation of an epistemological judgment by a learner. They assumed that learners who have to evaluate a knowledge claim might activate their general and their discipline-related epistemological beliefs (Stahl, 2009). The epistemological beliefs themselves can be differentiated further into different dimensions that a learner can activate. In agreement with Hofer, the four dimensions of certainty of knowledge, simplicity of knowledge, source of knowledge, and justification of knowledge (cf., Hofer, 2000) appear to be distinguishable.

In most cases, however, additional cognitive elements have to be activated to judge about the viability or "truth" of knowledge claims. First, some amount of *topic-related knowledge* seems necessary for an elaborated judgment. This includes content knowledge about the topic that has to be judged. To assume that an expert in a field is able to make more elaborated judgments than a layperson is reasonable. Second, *knowledge about the research methods* in a discipline can be activated insofar as the ways of producing and justifying of knowledge are specific for a certain discipline. For example, people with poor knowledge in physics will not have ample knowledge about the methods used within the field. They may mainly think of methods to measure physical quantities like temperature or mass, which are commonly assumed to be quite reliable and valid. Therefore, they might conclude from their superficial knowledge about methods that – which such valid methods – knowledge in physics should also be certain and stable. In contrast, a person with more knowledge about research methods in physics may consider the variety of methods which include complex and uncertain methods as well and, therefore, use this knowledge to make more differentiated epistemological judgments. Third, some *ontological assumptions* about the discipline the topic is assumed to belong to might be activated. Ontological assumptions are seen as assumptions about the reality of the world and of a specific discipline. This results in assumptions about topics and questions that certain disciplines investigate and their meaning of truth. Other cognitive elements might be *personal experiences* from one's discipline. When working in a specific research field, the interpretation of a knowledge claim might be different than when just reading about it. Furthermore, to understand the demands of the situation, *contextual cues* might be processed and used in the judgment. For example, when well-known experts in a particular discipline talk about their own research or when a student talks about the same topic, the processing might result in different judgments concerning the source of knowledge.

The main assumption is that a learner can activate different cognitive elements to form an epistemological judgment. This idea is elaborated in the following examples.

Anne, an expert in the field of physics, has to judge the certainty of the knowledge claim, "The mean distance between earth and sun is 149.60 million kilometers." To accomplish this, she might activate her content knowledge, her knowledge about the measurement method, and perhaps some ontological knowledge, before her conclusion is "true and certain." Jane, a novice in physics in her first semester at the university might activate different cognitive elements to judge the knowledge claim. She has some content knowledge from school, but no explicit knowledge about the methods to measure the distance between orbs, and still only relative stereotypical assumptions about the ontology of this discipline. Thus, she might refer to her discipline-related epistemological beliefs that she had developed in school. In her belief system, physics is a discipline which is able to generate certain and stable knowledge. Such assessments lead to the epistemological judgment that the statement is "true and certain." Bill is a layperson who is not interested in astronomy or physics. He has no content knowledge related to the topic, no knowledge about the methods (no ruler is long enough to measure this distance), or the ontology of the discipline, and only superficial discipline-related beliefs. Thus, he might activate his general epistemological beliefs, especially about the certainty of scientific knowledge and about the reliability of experts, and also some discipline-related beliefs about the disciplines he is interested in as an anchor for the judgment. He also judges the knowledge claim as "true and certain."

In a questionnaire with rating scales, all three persons would give the same answer. However, the conclusion that their responses are an expression for comparable epistemological beliefs would be wrong. Their epistemological judgments are built on different cognitive elements to evaluate the knowledge claim.

Next, imagine a second knowledge claim that has to be judged, "New results reveal that eggs are healthy for one's cholesterol level." Jochen, an expert in medicine, might activate his topic-related knowledge and his knowledge about methods (especially about other studies concerning this issue). Furthermore, his discipline-related epistemological beliefs about the certainty and stability of knowledge in this field are activated. For this complex issue, he might make a differentiated judgment. He agrees that the results in the specific study are "true and certain," because in his opinion the researchers might have published a good study. Therefore, he believes in the results. He might, however, doubt that the results can be generalized to other contexts or everyday behavior because of the complexity of this issue and contradicting results he knows from other studies. Also, his discipline-related epistemological beliefs emphasize the complexity, uncertainty, and preliminarity of knowledge in this discipline. Thus, he would disagree with the implicit generalization of the knowledge claim that eggs are healthy for the cholesterol level.

Sarah, a layperson in medicine, might "know" for years that eggs are unhealthy, because her doctor mentioned it to her several times. Such specific knowledge from an authority cannot be challenged. Thus, she also disagrees. Her epistemological judgment results from her epistemological beliefs about the source of knowledge and the certainty of knowledge. Bill knows little about this topic and research in medicine, but he is convinced that medicine is as accurate as physics. He is convinced that, in his opinion, the precise methods in physics are able to reveal certain knowledge. Consequently, he assumes that new methods in medicine are also able to produce certain results and believes the knowledge claim. Therefore, he is using discipline-related epistemological beliefs from the discipline of physics to evaluate claims in the discipline of medicine.

In this example, the cognitive elements that the hypothetical persons activate to judge the knowledge claim, again, show a broad variation. The notion that people try to activate and to combine different cognitive elements to make an epistemological judgment is reasonable to assume. This activation of different cognitive elements to judge a claim can be expected even more to take place when complex tasks or contents such as pro-and-contra argumentations or conflicting results are considered. The flexibility of people's epistemological judgments would depend on the richness of the cognitive elements that can be activated to evaluate a knowledge claim. Experts should be able to make more differentiated epistemological judgments in their discipline, whereas a layperson should only be able to make global, more stereotypical judgments over different situations. Epistemological beliefs are seen as an important part of the epistemological judgments, but their activation and interaction is, from this view, assumed to be mostly in combination with other cognitive elements. This would be in line with the architecture of the cognitive system discussed above that provides ample evidence for interacting elements that affect each other, but little evidence for systems that work alone and in separation.

The idea of a generative nature provides an explanation for some study results that are contrary to the perspective of stable epistemological beliefs. Kienhues, Bromme, and Stahl (2008) asked students of psychology to judge the discipline of genetic fingerprinting with the CAEB, a type of semantic differential to measure epistemological beliefs.[3] The students then either read a text about genetic fingerprinting, including numerous facts and descriptions of the methods, or a text that additionally included remarks about the uncertainties and problems with which the research field is struggling. After reading the text, students were asked to complete the CAEB for a second time. The epistemological judgments of the students did not change when the texts were in line with their first beliefs. No changes where found in the measurement when students rated genetic fingerprinting to be certain in the first measurement and read the text including all the facts. Similar results were found when students rated genetic fingerprinting to be uncertain in the first measurement and read the text including all the uncertainties. In the two other groups, significant changes were found. Students who rated genetic fingerprinting to be certain in the first measurement and read the texts including all the uncertainties significantly changed their judgments to a more uncertain view. Students who rated genetic fingerprinting to be uncertain in the first measurement and read the texts

[3] When the instrument was developed, no differentiation between epistemological beliefs and epistemological judgments was made.

including all the facts significantly changed their judgments to a more certain view. These results were replicated in other studies (cf., Bromme, Pieschl, & Stahl, 2010).

The likelihood that such short texts could have changed existing epistemological beliefs of the students would be unusual. But it might be possible to explain this shift with different cognitive elements that the students activated to make the ratings. All students had no deeper knowledge about genetic fingerprinting and only superficial discipline-related epistemological beliefs about the field. Thus, in the first measurement, they might have activated stereotypical views about the discipline or some general epistemological beliefs to make the judgments. The following texts gave them relevant information to understand research within the discipline of genetic fingerprinting. They focused either on "certain" facts or on the "uncertainties" of the discipline. It is reasonable to assume that the students used the new information for their second judgment. Significant differences were found when their internal judgments were different from the information in the text and no changes were found when their judgments were confirmed by the information in the text. These results cannot be explained with the assumptions that the students used separate epistemological beliefs for the judgment. An interaction between the epistemological beliefs and other cognitive elements (especially the knowledge from the new information) might be a better explanation for the results.

3.1.6.1 Statement III: Focusing on Detailed Interactions Between Complementary Cognitive Elements as the Smallest Unit to Understand the Flexibility of Epistemological Judgments Is Necessary

In most of the research about epistemological beliefs, researchers do not examine epistemological beliefs as such, but epistemological judgments. Most of the existing instruments do exactly this. From the view of the generative nature of epistemological beliefs, the idea that these judgments result from mutual activation of different cognitive elements is reasonable to assume. As a result, the same epistemological judgment can be reached in several ways. The epistemological argumentation leading to a judgment can be more or less sophisticated and more or less conscious to the learner. To understand how these epistemological judgments arise is essential to understanding in more detail epistemological beliefs and their application to different contexts.

From such a view, the following consequences are conceivable:

First, the notion of the activation of different cognitive elements in dependency of the demands of a specific context is in line with other research about the cognitive system, such as theories extended by Grossberg (1987a, 1987b) or the CI model of Kintsch (1998). The supposition follows that epistemological beliefs are emphasized as part of the cognitive system and are seldom activated as a sole element but should be seen in relation to other cognitive elements.

Second, the epistemological beliefs that a learner has might determine which other elements might be activated to make an epistemological judgment. If people have the beliefs that all knowledge is certain and that experts know the truth, they can believe a knowledge claim from an expert by ignoring other cognitive elements that might lead to a contrary judgment. On the other hand, if people have high prior knowledge in a discipline, activating *ju*st some epistemological beliefs to judge specific knowledge claims in the discipline would be less likely. Thus, other cognitive elements like prior knowledge might also activate suitable or inhibit unsuitable epistemological beliefs. In other words, the notion that the elements can complement each other or compete with each other is a logical conclusion.

Third, epistemological beliefs develop and change in interaction with other cognitive elements. As an expert in a field who is confronted with scientific work for years, the discipline-related beliefs (and the general beliefs) might change even if the expert is never explicitly discussing them.

Fourth, all cognitive elements that might be activated can be more or less elaborate or stereotypical and more or less conscious or automatic.

Fifth, investigating the flexibility and context dependency of epistemological judgments could provide explanations for obvious paradoxical results. The idea of sophistication of epistemological beliefs "as those beliefs which allow for context-sensitive judgments about knowledge claims" (Bromme et al., 2008) and cognitive flexibility "as the ability of our cognitive system to structure one's own knowledge in a variety of ways in adaptation to changing situational demands" (Spiro & Jehng, 1990) are comparable aims to ensure that the cognitive system is able to be flexible and context sensitive.

To examine the value of this idea, integrating new research methods into the existing body of work is necessary. Questionnaires do not help to understand how an epistemological judgment arises. Hammer and his colleagues use observations and interviews (e.g., Rosenberg et al., 2006), but employing these methods is not sufficient to understand possible interactions of cognitive elements in detail. Systematic research on a fine-grained level is necessary. The theories of Grossberg, Kintch, Barsalou, etc., as described above, might be used as heuristics or serve as inspirations that lead to *additions* to commonly used research designs on (at least) two levels:

First, the models and their mechanisms (e.g., uncertainties, heterarchical interactions) can be used as a heuristic to analyze and to understand the complexity of our own research fields in more detail. One problem might be that researchers generalize results too soon without understanding the mechanisms in detail. The specific learning context that might have led to the results is often reported and discussed on a highly superficial level. Differences to other studies are often reported in less detail – or even neglected. The conforming aspects found in different studies are often emphasized.

As discussed above, if an instrument does not lead to the same factor structure or to different results than existing studies show, then the differences are seldom discussed with an explicit comparison of the context, such as different learning scenarios, different types of tasks, or different types of cognitive variables of learners. Instead, too much energy is spent discussing the reliability problems of a particular instrument.

One important conclusion that can be drawn from the proposed view might be to analyze important elements of a learning situation and of the learners involved in much more detail. The development seems necessary of hypotheses and models of possible interactions between the cognitive elements in dependency of the concrete contextual demands. As a consequence, more process data should be collected, documented, and reported in much more detail in publications. Perhaps even more important is that the level of examination must also change to a more detailed level in which the interactions between the hypothesized elements can be examined.

Second, new research designs should be created and integrated into the existing spectrum. In visual perception, a common method is to work with stimulus thresholds. In these designs, a small group of subjects is confronted with a large series of systematically changing stimuli. The subjects participate for a longer period and the stimuli are changed in very small steps. This procedure yields measure responses in visual subsystems on a finer level and provides a basis from which to compare differences and consistency over different stimuli and to examine interactions between the elements. Conclusions can be drawn from the resulting data about the stability of subsystems over different contexts and about the interaction between each element.

One possibility, among others, for adapting this research method to research on epistemological judgments might be to measure cognitive elements such as prior knowledge, knowledge about methods, ontological views, discipline-related epistemological beliefs, and general beliefs in detail for a small group of subjects. Subjects might vary on the examined cognitive elements (e.g., by including laypersons, novices, semi-experts, and experts). The subjects are confronted with a whole *series* of knowledge claims or tasks that are systematically varied in reference to the variables assumed to have important effects. Methods, such as intensive interview techniques, can be employed to understand how each of the epistemological judgments is justified in relation to prior knowledge, general and discipline-related beliefs, the task, etc.

Another possibility might be to develop a fictional scientific discipline and to systematically change the information that participants receive about the discipline. This should result in different prior knowledge, methodological knowledge, discipline-related epistemological beliefs, and so on. Then the participants can be confronted with a series of knowledge claims, or tasks in relation to the discipline that the subjects are asked to judge. During the experiment, additional information about the fictional discipline can be given systematically to change some of the cognitive elements. This can be varied between participant groups. The suggested design provides many possibilities to examine the interactions of cognitive elements and the context.

At first sight, these designs might appear complex. On the other hand, they might lead to new insights into epistemological beliefs as a part of the cognitive system, epistemological judgments, and cognitive flexibility.

3.2 The Relationship Between Epistemological Beliefs, Epistemological Judgment, and Cognitive Flexibility

In this section, the hypothesized relationship between epistemological beliefs, epistemological judgments, and cognitive flexibility is described in more detail. As mentioned above, *epistemological judgments* are defined as learners' judgments of knowledge claims in relation to their beliefs about the nature of knowledge and knowing. They are generated in dependency of specific scientific information that is judged within a specific learning context. During a learning process, there are assumed to be ample opportunities to conduct epistemological judgments concerning the topic, the learning material, the learning tasks, and several other aspects of the learning scenario. For example, while reading an article in a textbook or the Internet, or while talking to a teacher or peers, epistemological judgments about the credibility of the source of knowledge and the justification of knowledge can be made. While interpreting the demands of a learning task or the content to be learned, epistemological judgments about the certainty and simplicity of the knowledge can be made, and so on. The spectrum for epistemological judgments can be assumed to increase with the task complexity. To make this more concrete, an analogy to the revised taxonomy of Bloom (cf., Anderson et al., 2001 might be helpful. Anderson and colleagues distinguish between cognitive processes of different complexity. The main categories of this dimension are *remember* (retrieve relevant knowledge from long-term memory), *understand* (construct meaning from instructional messages), *apply* (carry out or use a procedure in a given situation), *analyze* (break material into its constituent parts and determine how the parts relate to one another and to the overall structure), *evaluate* (make judgments based on criteria and standards), and *create* (reorganize elements into a new pattern or structure). Epistemological judgments can be assumed to be drawn in all categories of learning tasks (not only in the evaluate category). However, the more complex a task, the more epistemological judgments might be drawn. For complex learning material and complex tasks, learners might not just draw one epistemological judgment but different judgments (about the source and about the certainty of knowledge, about different material used, and so on). Learners might also change judgments during the learning process. For example, while reading text on the Internet, learners acknowledge that conflicting positions and different theoretical argumentations can be found. Therefore, their first judgment that the knowledge in this field is certain might be modified within the learning process.

Based on the reasons given, epistemological judgments can be assumed to be located at a metacognitive level. They might be connected to processes of metacognitive monitoring and controlling. Epistemological judgments, however, can be more or less conscious or automatic and more or less elaborate or stereotypical. Moreover, epistemological judgments can be assumed to affect all stages of a learning process (i.e., task definition, planning, enactment, and evaluation; c.f., Winne & Hadwin, 1998).

Cognitive flexibility is viewed in relation to the epistemological judgments – *not* in relation to the epistemological beliefs themselves. Analogous to Bromme et al. (2008), sophisticated epistemological judgments can be defined as context-sensitive judgments about knowledge claims. They have to be flexible and context specific to allow learners to judge the specific characteristics of different learning situations. As mentioned above, cognitive flexibility is defined "as the ability of our cognitive system to structure one's own knowledge in a variety of ways in adaptation to changing situational demands" (Spiro & Jehng, 1990). Therefore, the ability to draw sophisticated epistemological judgments is seen as a precondition enabling cognitive flexibility.

As an analogue to the CI model of Kintsch (1998), *flexible* epistemological judgments might depend (a) on the ability and motivation to interpret the demands of a given learning context, and (b) on a detailed and comprehensive basis of cognitive elements that can be activated to constitute the epistemological judgments.

(a) The *ability* to interpret the demands of a given learning context can be viewed in close relation to the basis of cognitive elements that a learner has, which is explained in point (b) below.

Motivational factors can be viewed in close relation to the level of involvement and the productivity of an epistemological judgment. Elby and Hammer (2001) assumed that epistemological beliefs about the tentative, relativistic, and complex nature of knowledge are not productive in many learning situations. From the view presented in this chapter, such "sophisticated" epistemological beliefs can always aid in reflection about a knowledge claim, but for "productive" epistemological judgments the context should always be considered. Therefore, the expression of such beliefs might not always be productive. Learners who perceive the teacher favoring a specific theory and that he is neglecting other points of view should think twice whether the best strategy might be to criticize the certainty of the theory or to adapt this view in the lessons and the tests of this teacher.

The level of involvement should refer to the assumption that it might be easier to accept the opinion of an expert or to accept an absolutistic view when a learner is not fully interested in the topic and is not motivated to seriously reflect about a knowledge claim. On the other hand, a high level of involvement might also require expecting some contents to be certain and to ignore judgments about the complexity and tentativeness of content. This can be necessary to progress and to be capable of acting in some situations. Following this reasoning, the context can be assumed to have a strong effect on the quality of a judgment, or even whether a learner is conducting a judgment at all.

As a consequence, the context should be taken seriously in research. Furthermore, the conclusion can be drawn that general or discipline-related epistemological judgments measured in an instrument will not necessarily reflect learners' epistemological judgments in a specific learning context.

(b) Flexible and adequate epistemological judgments also depend on a comprehensive basis of cognitive elements that can be activated to constitute the epistemological judgments. As discussed above, learners who are not familiar with a discipline and have only a few, superficial cognitive elements to constitute the epistemological judgments should be less reflective and more rigid in their judgments. Possible cognitive elements like prior knowledge of a topic or a discipline, knowledge about methods, ontological assumptions, and epistemological beliefs that might be activated and might work in interaction with each other have been discussed before. The focus of this section is on the epistemological beliefs. Epistemological beliefs are assumed to be located at the cognitive level (not at the metacognitive[4] level) as a network of elements that is usually activated in interaction with other networks of cognitive elements.

In congruence with the literature on epistemological beliefs, this view assumes that learners have general as well as discipline-related epistemological beliefs. Moreover, epistemological beliefs possibly also exist on the level of subdisciplines or pertaining to certain topics. Experts working in a discipline are usually focusing on specific research topics for years. They are confronted with several epistemological judgments concerning this special field of research during this time. If the idea that they are activating different cognitive elements to accomplish the judgments is true, then it is also suitable to assume that some cognitive elements (such as topic-related prior knowledge, ontological assumptions, and methodological knowledge in relation to the topic) are interacting repeatedly with the epistemological beliefs and affect each other. As a result, topic-related epistemological beliefs pertaining to the research field might arise. From this view, the possibility might therefore be that experts give highly sophisticated epistemological judgments concerning their own research field but might, nevertheless, give stereotypical epistemological judgments pertaining to other disciplines or even other research fields in their own discipline. Moreover, different dimensions of epistemological beliefs are assumed to exist, but they all refer to the core issue of viability or truthfulness of knowledge claims (see also Bromme et al., 2008).

Learners might also have knowledge about philosophy and the philosophical theories about epistemology. Knowledge of this type is defined as *knowledge about philosophy* and should be differentiated from personal epistemological beliefs. Knowledge about philosophy is a kind of prior knowledge that is located on a cognitive level and that can be activated when learners judge knowledge claims. Knowledge about philosophy can strongly effect the epistemological beliefs, but to have such knowledge is not necessary to develop epistemological beliefs.

Instead, epistemological beliefs are assumed to develop when learners are confronted with several knowledge claims that they have to judge during their life. Epistemological judgments are seen as a necessity for the development of epistemological beliefs. Learners need not reflect the knowledge claims on their own – they can also adapt direct or indirect judgments given by experts via direct conversation or through learning material like textbooks. Thus, when facts are emphasized and an

[4] From this view, the distinction between cognition and metacognition is challenging. Further elaborations of the view might result in a denial of these constructs.

impression is given from textbooks that knowledge is certain, a learner can adapt this view without deeper processing.

The confrontation with several contents in several disciplines should be necessary for the development of a comprehensive basis of epistemological beliefs on different (general and discipline-related) levels.

The main consequences of this view have been discussed above. The most important ones are to include more methods that allow understanding why learners constitute an epistemological judgment within a given context and to skip the idea that epistemological beliefs work in isolation from other cognitive elements. Another important implication is that from this view, there should be several different possibilities that contribute to the development of sophisticated epistemological beliefs. For example, opportunities to reflect on knowledge claims, such as conflicting research results, discussion of the history of science and how contemporary theories arose, deeper knowledge about philosophy that is related to the topics to be learned, and deeper understanding of the possibilities and limits of research methods might be used as different starting points.

3.3 Conclusion

In this chapter, cognitive flexibility is claimed to be more common in our cognitive system than usually assumed. If this would be true, then conceptual and methodological issues concerning epistemological beliefs should be affected. The necessity to differentiate between epistemological beliefs and epistemological judgments is suggested. Moreover, epistemological beliefs are assumed to interact with other cognitive elements to form epistemological judgments. The resulting judgments are seen as context dependent and flexible, even if the cognitive elements that can be activated for a judgment are relatively stable. These claims can be viewed as a foundation to include more fine-grained models and examinations into the research on epistemological beliefs. The aim is to understand if the interactions between cognitive elements and the resulting flexibility in relation to changing context that were found in disciplines examining other parts of the human information processing system might also be common elements of learning processes and of processes involving epistemological beliefs. This view might help to understand the construct of epistemological beliefs in relation to cognitive flexibility in more detail – even if the conclusion at the end might be that epistemological beliefs work alone, separated from all other cognitive processes, and are stable and context independent.

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Chapter 4
Spontaneous Cognitive Flexibility and an Encompassing System of Epistemological Beliefs

Marlene Schommer-Aikins

4.1 Introduction

In this chapter, the key components of cognitive flexibility involve the ongoing processes of detecting a need to change, changing, and monitoring the efficacy of the change. In order to maintain this continual process of constructing and reconstructing knowledge, learners need to be open to the notions of multiple sources of knowledge, multiple perspectives, continual reconstruction of their own knowledge representations, and tolerance for ambiguity and/or partial understandings.

The model presented in this chapter reflects three fundamental theory statements that link these ongoing processes to beliefs about the nature of knowledge and learning.

- Theory Statement 1: Beliefs in multiple solutions, multiple sources of knowledge, and connected knowing can motivate learners to search for more than one option for finding solutions or viewpoints. It would also drive them to look for multiple sources of knowledge (i.e., avoid an overreliance on a single source of knowledge).
- Theory Statement 2: Beliefs in tentative knowledge, separate knowing, and complex knowledge can encourage learners to reactivate their search for solutions over time or based on a trigger event.
- Theory Statement 3: Beliefs in gradual learning, complex knowledge, and tentative knowledge can encourage learners to resist premature closure.

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In this chapter, epistemological beliefs and cognitive flexibility are defined. Next, relationships between the two concepts are hypothesized. Then, a model is presented that illustrates how both epistemological beliefs and cognitive flexibility are intimately related to other cognitive factors, affective factors, situational demands, family culture, and world culture. Next, manifestations of the model are presented within the context of willingness to argue. Finally, the model is used to predict the absence of cognitive flexibility.

4.2 What Is Cognitive Flexibility?

In the hypothetical model that will be presented in this chapter, cognitive flexibility is characterized as individuals considering and/or embracing alternative choices or responses in a balanced and mindful way. Here "balanced" implies change that occurs after consideration of a wide array of choices or responses as opposed to a quick impulsive change. And "mindful" implies the monitoring of the exploration process and the subsequent choices made. Hence, cognitive flexibility involves adaptability including the following: (a) seeing the potential need or benefit to change, (b) making changes after considering alternative choices, (c) monitoring the efficacy of change, and (d) presuming that the changes may not be permanent.

How might cognitive flexibility manifest itself? Cognitive flexibility seems readily apparent when individuals think or behave in particular ways. For example, individuals change or adapt to situational demands (e.g., change a public presentation at the last minute when they discover the audience is different than they expected), can see alternative choices, seek out assertions or evidence that is different from their preexisting knowledge, display willingness to revisit thoughts without explicit provocation, work with ideas playfully, tentatively, and feel positive in this process, and adapt to others' forms of communication or demands. In sum, cognitively flexible individuals are vigilant in monitoring for changes in situational demands and/or may seek change without provocation. However, their changes occur after they have taken time to reflect on the utility of the change or – if the change is quick due to situation demands – reflection takes place after the change has occurred.

Broadly speaking, cognitive flexibility can be seen as a habit of the mind. Instead of automaticity being described as routine, mindless responses to set situations, individuals with cognitive flexibility automatically think deeply and adaptively. Their default cognition is to see a need to revisit their thinking or their mental representations. They anticipate or consider multiple solutions or perspectives; they purposely refrain from premature closure.

The question is this: what can lead to this habit of mind? According to Cañas, Fajardo, and Salmerón (2006), cognitive flexibility training focuses on two cognitive flexibility theories: knowledge representation and attentional processes.

4.3 Cognitive Flexibility via Knowledge Representation and Shifting Attentional Processes

Cognitive flexibility theory has been spearheaded by Spiro and many of his colleagues (e.g., Jacobson & Spiro, 1995; Spiro, Coulson, Feltovich, & Anderson, 1994; Spiro & Jehng, 1990, 1995). Its early conception was based on the idea that knowledge representation in the form of schemata was appropriate for well-structured concepts. However, schema theory was woefully inadequate for ill-structured concepts (Spiro et al. 1994). Ill-structured domains defy simple organizational links. These domains are highly interwoven, may involve multiple causal relations, multiple solutions, or no solutions at all. Examples of ill-structured concepts include the causes and solutions to problems such as the following: poverty, prisoner recidivism, and political warfare (Kitchener, 1983).

Spiro called for a mental representation different from schema which allows the mind to crisscross the landscape of ideas, intertwining the ideas in multitudinous ways. With each crisscross, there is opportunity to assimilate, and, more importantly, accommodate new knowledge (Spiro et al., 1994).

Along with this mental representation of ill-structured concepts came the notion of the role that mental representation plays in human cognition. The implication was that humans needed to be more than mere robots. They needed to think flexibly in order to embrace new, unimagined concepts and to use their knowledge in new, unimagined situations. Spiro and Jehng (1990, p. 165) asserted that

> by cognitive flexibility, we mean the ability to spontaneously restructure one's knowledge, in many ways, in adaptive response to radically changing situational demands…This is a function of both the way knowledge is represented (e.g., along multiple rather than single conceptual dimensions) and the processes that operate on those mental representations (e.g., processes of schema assembly rather than intact schema retrieval).

Spiro, and many others (e.g., Demetriadis, Papadopoulos, Stamelos, & Fischer, 2008; Jacobson & Spiro, 1995; Scheiter, Gerjets, Vollmann, & Catrambone, 2009) who followed his line of work, began to test instruction that encouraged learners to embrace ill-structured concepts and to transfer their learning to new situations. Presumably, the instructional process was encouraging the development of highly complex knowledge representations. From this line of thinking, instructional techniques were tested that attempted to expose learners to multiple examples of a concept that varied in irregular ways. Use of hypertext learning environments (e.g., web-based texts that have embedded links to many other texts) has been shown to be useful in allowing learners to access knowledge bases in numerous, idiosyncratic ways. Concepts can be juxtaposed to help learners see family resemblances among the irregular variations within a concept (Spiro, Collins, & Ramchandran, 2007).

However, Cañas et al. (2006) point out that there are at least two limitations to the hypertext instructional approach. First, providing the rich technology environment requires a great deal of resources and time investment. Second, it is unlikely that learners can be exposed to all possible scenarios, certainly not for all ill-structured concepts.

A second instructional approach has focused on the learner's attentional processes. The notion behind this instruction is that the reason learners are not cognitively flexible is that when they are faced with an environmental demand that requires a shift in attention, they are unable to disengage their attention on their present focus and/or are unable to reengage their attention to more critical areas. Instructional programs that vary the amount of attention and effort devoted to varying aspects of a task explicitly guide the learner to switch attention when moving from one subtask to another subtask. Researchers have found this form of instruction has improved learners' efficiency in moving from one task to another and their ability to transfer attentional shifting in new, unprompted learning situations (Kramer, Larish, & Strayer, 1995).

Although both of these instructional techniques are admirable, they are not always effective. Some learners simply do not respond to the enriched, complex, flexible environment (Bråten & Strømsø, 2006; Scheiter et al., 2009). Other learners are not comfortable in this environment. Yet, this research does provide support for the key components of a model for learners who are cognitively flexible without explicit instruction.

4.4 Spontaneous Cognitive Flexibility

This chapter focuses on individuals who are already cognitively flexible. They come to the learning environment ready to crisscross the landscape of ideas, evidences, and more. What allows an individual come to the learning environment predisposed to cognitive flexibility? The hypothesis being offered here is that individuals with mature epistemological beliefs, epistemological beliefs that support higher-order thinking, will default to flexible thinking. Other, closely related beliefs will also play a critical role in spontaneous flexible thinking.

In this section, first epistemological beliefs are explicated. What are they? How have they been linked to learning? Next, research is presented that indicates individuals with more mature epistemological beliefs are found to be better learners in ill-structured domains and are more responsive to hypertext learning environments that encourage the crisscrossing of ill-structured landscapes. Then, a model that makes explicit hypothetical links between epistemological (and closely related) beliefs to cognitive manifestations of flexibility is described. This model is then used to explain individuals' willingness to argue. Finally, the utility of this model in explaining the absence of cognitive flexibility is presented.

4.5 An Array of Epistemological Beliefs

In this chapter, a more encompassing view of epistemological beliefs is used. The reason that the model is not limited only to beliefs about knowledge is that the larger array of beliefs provides more explanatory power in the cognitive flexibility–epistemological belief system model. And this more entailed model emphasizes the fact that epistemological beliefs work with other systems (Schommer-Aikins, 2004). A brief history of epistemological beliefs and closely related beliefs and the clarification of terms are as follows.

In the past, learners' beliefs about knowledge, its source, stability, and justification were conceptualized in a unidimensional paradigm, for example, Perry's (1968) work with Harvard undergraduate's views on education and Kitchener and King's (1981) work with reflective judgment. In 1990, epistemological beliefs were reconceptualized as being composed of a system of beliefs that may or may not develop in synchrony (Schommer, 1990). A minimum of five beliefs were hypothesized: (a) stability of knowledge (ranging from unchanging to continually evolving), (b) source of knowledge (ranging from handed down by experts to derived from reason and evidence or multisourced), (c) structure of knowledge (ranging from isolated bits to integrate, complex webs) (d) speed of learning (ranging from quick or not-at-all to gradual), and (e) ability to learn (ranging from fixed at birth to improvable).

Two critical aspects of this epistemological belief system are important to keep in mind: whether or not these beliefs develop in synchrony and what is meant by more mature beliefs. In 2004, Schommer-Aikins attempted to clarify that these beliefs may or may not develop in synchrony. If they do develop in synchrony, then stage-like patterns may be evident as has been hypothesized by others (Baxter-Magolda, 2004; Kitchener & King, 1981). However, this synchronous development is not guaranteed and may be particularly untenable during periods of developmental transitions. For example, young learners may come to believe that knowledge is highly complex, yet during their adolescent years they may not have wrestled with the notion that knowledge is changing (Boyes & Chandler, 1992). The important point, practically speaking, is that because a learner appears mature on one or two beliefs, it cannot be assumed that the learner is consistently mature across all beliefs.

Second, the idea of "mature" or "sophisticated" beliefs needs to be clarified in order to avoid a limited characterization of maturity and to avoid being judgmental. Mature beliefs do not mean that the learner is at the extreme end of a spectrum (Schommer-Aikins, 2004). Rather, as Perry suggested in 1968, the epistemological belief system theory asserts that as learners' beliefs mature, their beliefs become more encompassing with a strong tendency toward one side of a continuum. Mature beliefs are NOT truncated. For example, if the learners started out with a strong belief that knowledge is never changing, as they matured they would start to consider some knowledge does change. As their beliefs began to support higher-order thinking, their belief about the stability of knowledge would be revised to conclude much of knowledge changes. However, what is critical is that their mature belief is encompassing. There would still be belief that some knowledge is indeed stable. Hence, the mature belief is encompassing variability in knowledge. Indeed, it has been hypothesized with this particular belief, an extreme truncated belief in the stability of knowledge, would lead to either rigid/nonadaptive thinking (knowledge never changes, hence, I cannot learn anything that is inconsistent with what I already know) or noncommittal/indecisive thinking (knowledge is in constant flux with no end in sight). The truncated rigid thinking would limit learning to that which fits into prior knowledge acquired earlier in life at the least, or failure to transition to cognitive maturity at the worst. The truncated/noncommittal thinking could lead to an inability to make decisions (or gullibility to follow everyone else's decisions) at the least, or to a mental breakdown at the worst.

In sum, mature beliefs do not denigrate remembering facts, adhering to authority, or seeking definitive answers. Rather, mature beliefs will tend to support higher-order thinking the majority of time. However, when the situation demands it, more basic thought processes will be supported. For example, a well-trained surgeon needs to make precise decisions second by second and make shifts instantaneously if the patient takes a sudden turn. This encompassing characteristic of mature epistemological beliefs is important for a balanced approach to thinking. Balance is a theme we will return to when discussing the quality of cognitive flexibility.

The beliefs generated by another team of researchers who moved in their own direction from Perry's work will be included in this model. Noting that Perry's work was based primarily on men, Belenky and her colleagues (Belenky, Clinchy, Goldberger, & Tarule, 1986) saw a need to investigate epistemological beliefs of women. After interviewing a large sample of women, they concluded that women may hold "positions" or beliefs about the process of knowledge acquisition that entailed their own role and that of experts. These positions ranged from unquestioning acceptance and the self-taking on a subservient role to active questioning and the self-evaluating incoming assertions. Over the past several decades, the positions or ways of knowing that have become of greatest interest are connected knowing and separate knowing (Clinchy, 2002). These two ways of knowing are considered the most advanced. The connected knower initially makes an effort to understand someone else's perspective, to walk in their shoes metaphorically speaking. Once the connected knower grasps others' perspectives, evaluation of their assertions occurs. The separate knower initially plays the devil's advocate. Only after doubting and questioning have occurred, are they likely to take on the other's perspective.

Two important issues about ways of knowing must be kept in mind: the gender-relatedness (as opposed to gender-specific) nature of these ways of knowing and what is meant by a mature way of knowing. Research indicates that men will have a stronger propensity toward separate knowing and women will have a stronger propensity toward connected knowing (Galotti, Clinchy, Ainsworth, Lavin, & Mansfield, 1999; Marrs & Benton, 2009). However, these gender differences have not been consistently found (Clinchy, 2002). Hence, the expression that these ways of knowing may be gender related, but not gender specific, is typically used. Furthermore, both ways of knowing are thought to support higher-order thinking; that is, the most mature individuals are capable of both ways of knowing (Clinchy, 2002).

Once again, it is apparent that maturity or advanced beliefs involve encompassing beliefs. For ways of knowing, it means that the learner will hold both ways of knowing. The challenge is which way of knowing to use when, or how to carefully blend both ways of knowing. Research has supported the idea that both ways of knowing support higher-order thinking (Schommer-Aikins & Easter, 2008).

In sum, an array of beliefs will be included in the model being hypothesized. Included in this array are beliefs about knowledge (source, stability, and structure), beliefs about knowledge acquisition (speed and ability), and beliefs about ways of knowing (connected knowing and separate knowing). For efficiency sake, the complete set of beliefs will be referred to as an *encompassing system of epistemological beliefs* (ENCOMP EB).

The following are just a few examples of how ENCOMP EB have been shown to link to different components of cognitive flexibility. The more learners believe in tentative knowledge, the more likely they are to avoid premature closure (Schommer, 1990). The more learners believe learning is gradual and knowledge is organized as complex interwoven concepts, the more likely they are to use study strategies that support higher-order thinking (Mason & Scirica, 2006; Moschner, Anschuetz, Wernke, & Wagener, 2008; Schommer, Crouse, & Rhodes, 1992; Schommer-Aikins & Easter, 2007). The more students believe in connected knowing and separate knowing, the more likely they are to believe in gradual learning and perform better in complex learning tasks (Schommer-Aikins & Easter, 2008). The more learners believe that the ability to learn is improvable, the more likely they are to persist when the task is difficult or the answers do not come swiftly (Dweck & Leggett 1988; Schommer & Walker, 1997).

The most important point of reflecting on the links between ENCOMP EB and cognitive flexibility comes from the theory and evidence that these beliefs appear to have both direct and indirect effects on learning and thinking. Researchers have consistently suggested and found support for the notion that the array of epistemic beliefs has the potential to set the standards for what it means to "know." These standards elicit study strategies and thought processes. In turn, the study strategies and thought processes result in focus of attention and, ultimately, knowledge representations that have the potential to support higher-order thinking (Bendixen & Rule, 2004; Schommer-Aikins, 2004). The question is this: what is the intimate relationship between the ENCOMP EB, cognitive (and affective) processes/representations, and, ultimately, cognitive flexibility?

4.6 Research Linking the Encompassing System of Epistemological Beliefs to Cognitive Flexibility

Much of the research that links ENCOMP EB to cognitive flexibility involves placing learners in an environment that should induce cognitive flexibility or in an environment that will entice cognitive rigidity. The key findings are that learners with more mature ENCOMP EB are more responsive to enriched environments and more resistant to environmental factors that are conducive to rigid thinking.

Work by Bråten and Strømsø (2006) indicates that not all students benefit when reading multiple texts. College freshmen read either a single text or multiple texts about ADHD. Both groups had adequate understanding on the basic facts of the text.

However, deeper understanding of conflicting ideas and text integration were only evident for students with mature epistemological beliefs who had read the multiple texts.

Individuals with more mature ENCOMP EB and higher cognitive abilities have been shown to flexibly use their prior reason in reasoning tasks. In study by Sá, West, and Stanovich (1999), prior knowledge facilitated reasoning in half of the tasks presented to participants. In the remaining tasks, prior knowledge interfered with the reasoning. When provided cues that prior knowledge should not be taken into account, only individuals with more mature beliefs in complex and tentative knowledge refrained from interference from their prior knowledge. Since these results were found using both a syllogism task and a judgment of a physical height task, researchers concluded that critical thinking and aspects of thinking flexibility tended to be domain general.

Providing questions that encourage learners to reflect on ill-structured text by moving back and forth across case examples in the text has been shown to enhance the learners' acquisition and transfer of knowledge. Furthermore, learners with more mature ENCOMP EB responded most favorably to the questions compared to students with less-mature epistemological beliefs. In other words, more mature ENCOMP EB leads students to benefit from instructional techniques that involve deeper processes and developing more flexible knowledge structures. In this study, epistemological beliefs were defined as believing that knowledge is complex with multiple interconnections and that the learner must put forth effort to learn (Demetriadis et al., 2008).

Evidence suggests that beliefs about the speed of learning are related to cognitive flexibility. Learning in a hypertext environment and being provided with several presentations of material, each presentation linking ideas in different ways, resulted in enhanced transfer of knowledge in problem-solving essays. Two critical features of these results were that students with more mature ENCOMP EB benefited the most from the hypertext environment and this effect was not found until a delayed measure was taken (Jacobson & Spiro, 1995). In other words, ENCOMP EB appears to help the students be responsive to a rich, constructivist environment. And it takes time for students to assimilate the complex array of knowledge acquired.

Learners who believe knowledge acquisition takes time have been shown to display cognitive flexibility and adaptability in a controlled hypermedia environment. Scheiter et al. (2009) examined a number of different learner factors in relation to students using efficient yet effective strategies to learn basic information and transfer problems. The most effective learner factors were prior knowledge, the belief that learning takes time, valuing the content area being learned, motivation, and use of cognitive and metacognitive strategies during the learning process. The authors' critical point was this: learner characteristics beyond prior knowledge need to be taken into account in the efficient and effective use of hypermedia. The point being made here is that mature ENCOMP EB and highly flexible activities on the web lead to enhanced academic performance. Alternatively, students with naïve ENCOMP EB appeared to be overwhelmed or unresponsive to text formatting that requires cognitive flexibility.

4.7 Proposed Model of Cognitive Flexibility and the Encompassing System of Epistemological Beliefs

The most fundamental premise to reiterate here is that epistemological beliefs can set the standards of what it means to learn or to know, that those standards determine the study strategies that individuals use, and subsequently, that study strategies build the mental representation. The following reiterates the definition of cognitive flexibility being used: cognitive flexibility involves adaptability including (a) seeing the potential need or benefit to change, (b) making changes after considering alternative choices, (c) monitoring the efficacy of change, and (d) presuming that the changes may not be permanent.

Two key concepts are needed for cognitive flexibility: mental representation and vigilance (attention). Cognitively flexible individuals anticipate more than one solution, more than one perspective, and more than one source of knowledge. Cognitively flexible individuals are vigilant in watching (consciously or unconsciously) for the need or desirability of change. Figure 4.1 shows a general overview of the vigilance and mental representation cycle that is presumed to be ongoing in the cognitively flexible individual. Note that the ENCOMP EB is both an influence to change and subject to change in this cycle. In other words, change in the mental representation can influence growth in ENCOMP EB. For adolescents, that could mean regression in ENCOMP EB as well.

Figure 4.2 is a hypothetical model that displays at least one potential set of links between ENCOMP EB and cognition that presumably leads to cognitive flexibility. The three main components that seem critical for individuals to construct knowledge into a complex mental representation are seeking and integrating multiple perspectives, multiple solutions, and multiple sources. Beliefs about the structure of

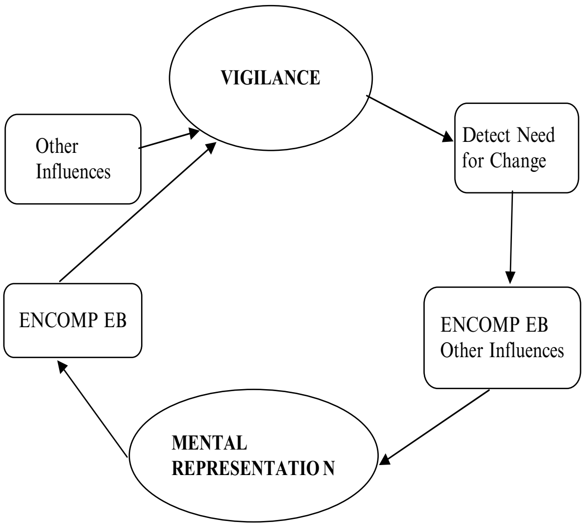

Fig. 4.1 Cognitive flexibility and ENCOMP EB cycle

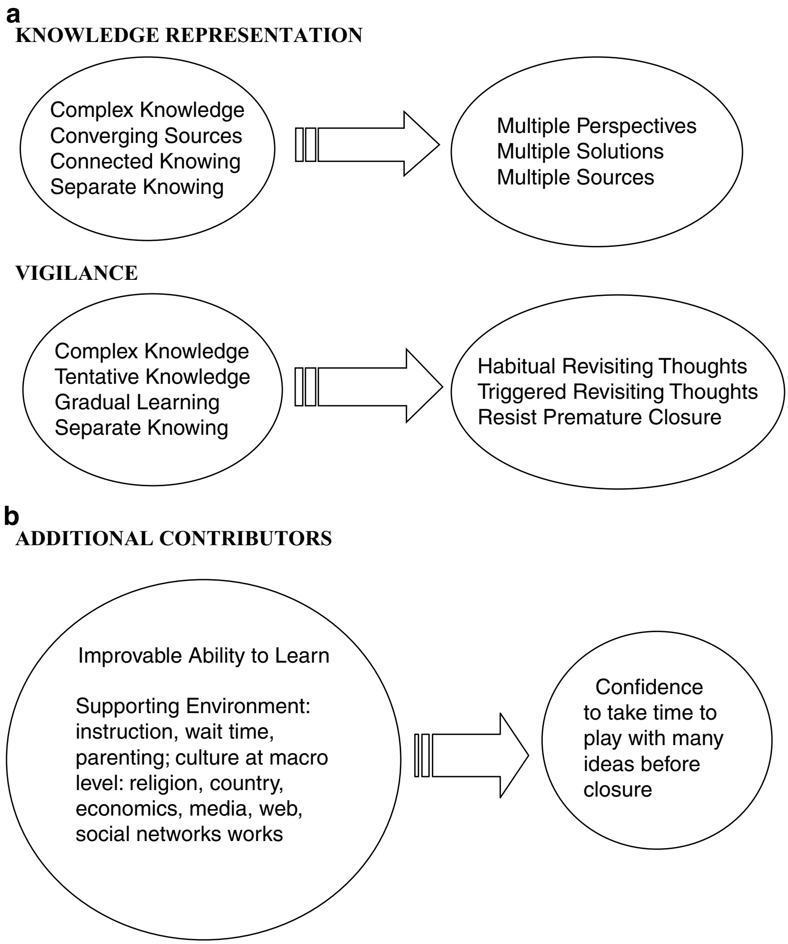

Fig. 4.2 (**a**, **b**) Model of cognitive flexibility as a derivative of ENCOMP EB

knowledge, the source of knowledge, and ways of knowing are beliefs that potentially lead individuals to construct complex, multiplistic knowledge representations from multiple sources. Connected knowers are focused on others' perspectives and believe that there are more perspectives other than their own. Those who believe knowledge is complex are also more likely to assume multiple perspectives as well as multiple solutions and multiple sources. Individuals who see knowledge sources as the convergence of both empirical evidence and rational thought are likely to seek multiple sources of information. Separate knowers will likely juxtapose knowledge from multiple sources in order to help them detect conflict, corroboration, or disconfirmation among the sources.

Three main components seem necessary to maintain vigilance (attention either consciously or unconsciously) in order to seek change or adaptation. These components include the following: revisiting thoughts routinely (habitual vigilance), revisiting thoughts when triggered or cued internally or externally, and avoiding premature closure. The two revisiting forms of vigilance are important for change occurring after a mental representation has already been established. The avoidance of premature closure is important for vigilance (self-monitoring) while learning (knowledge construction) is in progress.

Beliefs about ways of knowing, stability of knowledge, structure of knowledge, and speed of learning could all contribute to vigilance. Separate knowers, with their devil's advocacy stance, would constantly instigate monitoring of the knowledge representation. Does what is being learned make sense? Is it coherent within itself? Is it consistent with prior knowledge? Is it consistent across sources? Individuals, who believe knowledge is tentative, would habitually be sensitive to changes in the situation that would require shifts in knowledge representation. These same individuals would embrace cues in the environment that suggest revisiting and reviewing existing knowledge structures. Individuals who believe knowledge is highly complex may be open to new perspectives and new solutions as they come to their attention. And individuals who see learning as a gradual ongoing process would be more willing both to wait for closure and to take the time to revisit existing thoughts. In sum, separate knowers are actively questioning and doubting (or monitoring), and beliefs about the tentative knowledge, complex knowledge, and gradual learning are guiding what is being questioned and the time investment needed for the questioning.

Additional components have been added to this model, which include beliefs about one's own ability and environmental support including, academic, familial, and cultural. These additional components have been included here to emphasize that ENCOMP EB does not function in a vacuum. It is a system of beliefs among other systems. And, a hindrance anywhere in the system could lead to failure for learners to actually manifest cognitive flexibility. Hence, even if learners believe that there are multiple sources and multiple solutions, they may be reticent to refrain from premature closure if they do not have confidence in themselves as learners, that is, if they do not believe that they have the ability to find better conceptions or understandings with further investigation. As another example, even if learners have all the components necessary for cognitive flexibility, if the instructional environment does not give extended periods of time for reflection or if assessment demands a simple, certain answer, cognitively flexible learners will adapt to the environment and respond in the required manner. That does not mean that the learners are not cognitively flexible, indeed, they are flexible by adapting to the environment that demands immediate, singular, definitive answers.

4.8 Research Linking ENCOMP EB and Cognitive Flexibility in Argument

The utility of this model can be made evident when applied to a specific context. Here, it is presented in explaining the degree to which learners are willing to engage in argument. The extant research that links epistemological beliefs to argumentation and willingness to argue highlights the need for cognitive flexibility in order to engage in quality argumentation. Indeed, cognitive flexibility has been shown to be positively related to argumentativeness and tolerance for disagreement. Conversely, cognitive flexibility has been shown to be negatively related to verbal aggression (Martin, Anderson, & Thweatt, 1998). To date, the beliefs most often found to link to argumentation are beliefs in converging sources of knowledge, complex knowledge, the certainty knowledge, and separate knowing.

A link has been found between ENCOMP EB and argumentation among eighth-grade students (Mason & Scirica, 2006). Students were required to generate arguments, counterarguments, and rebuttals for two controversial issues (global warming and genetically modified food). The students needed to justify each aspect of their argumentation based on what they read. ENCOMP EB predicted argumentation performance. Students with an evaluativist (multiple solutions that can be prioritized by context and quality of evidence) position outperformed other students with multiplist positions (mulitiple solutions with no prioritizing, in other words one solution is as good as another). ENCOMP EB effects were found after topic knowledge effects were taken into account.

Schommer-Aikins and Easter (2009) found that the more students believed in separate knowing, the more willing they were to engage in argumentation and the more likely they were to define *argument* in their own words as a constructive form of communication. Students who did not believe in separate knowing were less willing to argue and more likely to define *argument* as a destructive form of communication with the ultimate goal to cause psychological pain to another.

Nussbaum and Bendixen (2003) found that, along with the need for cognition and extroverted personality, students with beliefs in simple and certain knowledge were more likely to avoid arguing.

Schommer-Aikins and Hutter (2002) found that the more adults believed in complex knowledge structure, the more likely they were to display flexible thinking. Specifically, when faced with highly controversial day-to-day topics, these adults were willing to consider multiple perspectives, take time to reflect on the issues, acknowledge the complexity of the issues, and, most relevant to this discussion, entertain the idea of changing their position on the topic.

4.9 Proposed Model Applied to Willingness to Argue

This model is now presented in the context of willingness to argue. How might this model play itself out in an individual's willingness to argue? What needs to happen cognitively for someone to be willing to argue? Much of the research would suggest four essential factors: (a) argumentation is seen as a positive form of communication, (b) a person is willing to explore all possible perspectives of the argument, (c) a person is willing to provide evidence or logic for each perspective, and (d) a person believes that the ultimate purpose of this form of communication is to provide the best conclusion or to provide the best array of conclusions.

According to Infante and Rancer (1996), argumentation is a constructive form of communication in which people attempt to present a premise and provide evidence for it. Furthermore, they are able to provide counterevidence to arguments against their premise. Argumentation has been linked to many positive attributes, such as authoritative parenting in which parents reason and dialogue with their children. Verbal aggression, on the other hand, is seen as a destructive form of communication. The goal is to cause psychological distress or harm to another such as results from authoritarian parenting in which parents use threats and coercion with their children (Schommer-Aikins & Easter, 2009).

The notion that willingness to argue involves willingness to reflect on all possible perspectives and the supporting evidence behind these perspectives comes from research on skills of argument (Kuhn, 1991; Mason & Scirica, 2006). In order to engage in skillful argumentation, individuals need to reflect on their opponents' perspective. For example, what issues are likely to be brought up and what evidence or rationale is there that supports these opposing issues. Only through this process of reflection on opponents' perspectives can individuals reflect on a strong rebuttal to their opponents' stance.

Finally, the idea that willingness to argue is related to the ultimate goal of providing quality conclusions rather than psychological harm to the opponent comes from research linking ways of knowing to willingness to argue (Schommer-Aikins & Easter, 2009). When completing self-report measures on willingness to argue, individuals with strong beliefs in separate knowing indicated more willingness to argue compared to individuals with weaker beliefs in separate knowing. Furthermore, when asked to define argument in their own words, those more willing to argue defined argument as a positive form of communication. For example, one wrote that argument is "a position on an issue or question"; and another wrote "I define argument as a 'lively discussion." In contrast, those less willing to argue defined argument in more maladaptive terms, for example, argument is "anger between two or more people over differing opinions"; "fights, high blood pressure, tension, anger" (Schommer-Aikins & Easter, 2009, p. 127).

Figure 4.3 (see next pages) provides a visual display of how willingness to argue can be seen in the hypothetical cognitive flexibility/ENCOMP EB model. If willingness to argue involves taking on others' perspectives and the support that goes along with these other perspectives, then individuals would need to believe that there really are multiple perspectives. In addition, these other perspectives have support in their own right. If willingness to argue entails careful and continuous reflection while preparing for the argument, during the argument, and in a truly reflective act, after the argument, then individuals need to be vigilant. That is, they would need to continue to reflect on all perspectives and question themselves as well as others. They would need to be sensitive during the argument when their perspectives and arguments are not as convincing as the arguments of others. In other words, these individuals would need to believe that the process of argumentation is an ongoing perusal of complex knowledge representations that may change due to incoming (external from opponent or internal from self) knowledge representations.

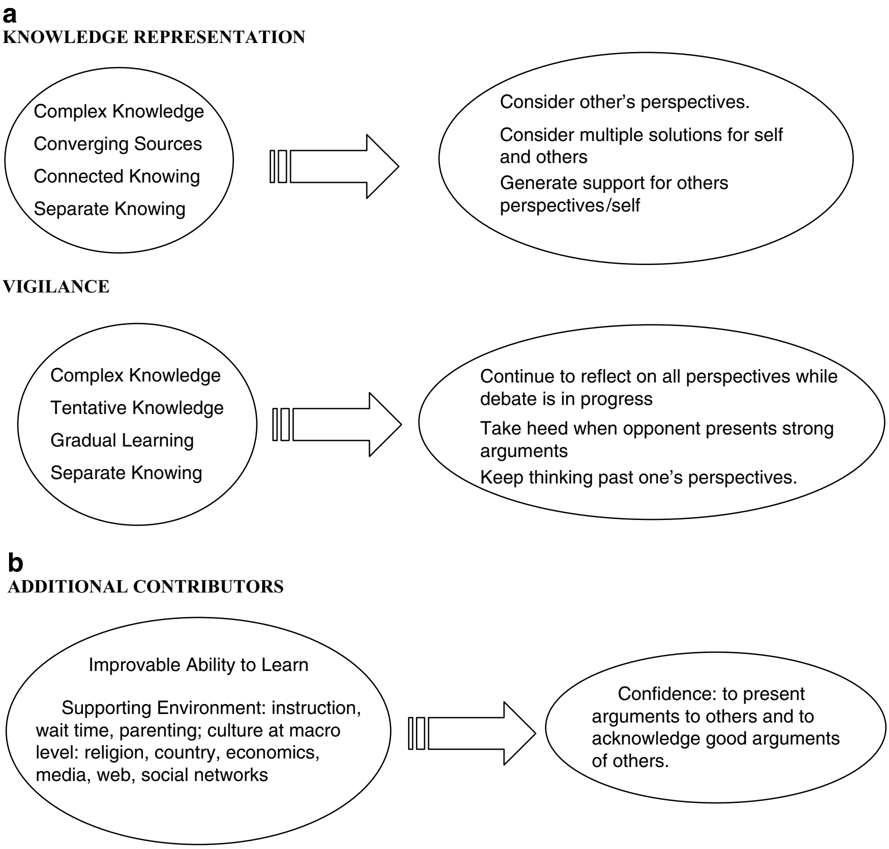

Fig. 4.3 (**a**, **b**) Willingness to argue in the cognitive flexibility/ENCOMP EB model

4.10 Using the Model to Explain the Absence of Cognitive Flexibility

Although the ENCOMP EB model was derived with spontaneous cognitive flexibility in mind, it can also explain what may happen when cognitive flexibility is absent or has gone awry. Three maladaptive processes are discussed: cognitive rigidity, cognitive indecisiveness, and unresponsiveness to instructional techniques meant to encourage cognitive flexibility.

Cognitive rigidity is indicated by a failure either to detect a need for change or a refusal to change in the face of situational demands for change. If learners have a strong propensity toward separate knowing in the absence of some degree of connected knowing to counterbalance the separate knowing, then learners may refuse to take on another's perspective. They can resist change by generating a barrage of counterarguments to prevailing evidence. If learners have a strong belief in certain knowledge, then they may cling to their prior knowledge, focusing only on justification that supports what they already know. Thus, with cognitive rigidity, prior knowledge is not subject to change.

Cognitive flexibility can also be absent due to cognitive indecisiveness. Cognitive indecisiveness is indicated by either avoiding making a decision or changing one's view capriciously. If learners have a strong propensity toward connected knowing in the absence of some degree of separate knowing to counterbalance their connected knowing, then learners may change their thoughts to match those of anyone they encounter. With their lack of objectivity, learners can be misled by others. If they have strong beliefs in tentative knowledge without some degree of belief in certain knowledge, then they can live in a state of indecisiveness. Always sensing either a state of incomplete knowledge or that tomorrow brings a different answer, making decisions can become a daunting task.

Cognitive inflexibility can also be due to unresponsiveness to instructional techniques meant to encourage cognitive flexibility. Unresponsiveness to rich, complex instructional environments is apparent when individuals do not construct complex knowledge representations or when they become overwhelmed in these environments. The explanation generated from the model may differ depending on the instructional technique, for example, hypermedia or attention control. If learners have a strong belief that knowledge is simple, then this belief could lead to shallow processing and minimal comprehension monitoring. Hence, no effort would be make to make multiple links across the complex terrain of a hypertext. If learners believe that the process of knowledge acquisition is a series of simple steps, then they may resist the attentional control devices meant to shift their attention through different aspects of the task at hand.

Asynchronous development is an important consideration in these hypothetical examples. In the model of spontaneous cognitive flexibility, all aspects of the learner are at their best. For example, both separate knowing and connected knowing are embraced. Each counterbalances the other, which helps avoid cognitive rigidity and cognitive indecisiveness. Belief in the tentativeness of knowledge is balanced with a degree of belief that some knowledge is stable. In short, if anything in the model is awry and there are no compensatory mechanisms in place, then cognitive flexibility will either be lacking or be limited.

4.11 Cognitive Flexibility with a Sense of Balance

It is important to reiterate that cognitive flexibility does not mean an inability to come to a conclusion or an inability to identify a single solution. Rather, cognitive flexibility is seen as a positive attribute, which allows individuals to change or modify their thinking when there are situational demands or when reflection makes them realize that they need to change with the times. Cognitive flexibility also involves an element of wisdom or balance. It is not impulsively changing. It is not changing only after extraordinary pressure has been put on the individual. It is changing due to sensitivity to internal or external cues. Habitual vigilance helps the individual be sensitive to the benefit of change. ENCOMP EB is likely an important component that guides the mind to both the knowledge representation and attentional processes that lead to cognitive flexibility. Future research can explore the details of this model. Future researchers can juxtapose models and research results to create more comprehensive models that link ENCOMP EB to cognitive flexibility.

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Chapter 5
Personal Epistemology and Philosophical Epistemology: The View of a Philosopher

Richard F. Kitchener

5.1 Introduction

It is a fact recognized as far back as the Greeks that life has a temporal dimension, in fact a developmental dimension. Individuals' concepts, beliefs, theories, and knowledge change over time as they experience the world and learn. This is a view that has long been a part of common sense. But more than this, individuals' conception of the nature of knowledge – their epistemology – also changes over time. This is a new and important notion, one that is relevant to a variety of academic areas.

Individuals are said to have a *personal epistemology* (PE), a theory of knowledge that they themselves construct over time. But what this PE is, how it is to be studied and explained, and the bearing of such an inquiry on cognitive acquisition and cognitive flexibility are questions that continue to invite discussion and reflection. Likewise, the question of the relation between PE and general epistemology is also a question worth exploring.

The recent flourishing of research on PE has resulted in an extensive series of educational and psychological studies as well as a well-recognized cataloguing of the various theoretical approaches to this field (Hofer & Pintrich, 1987, 2002). These include *epistemic cognition*, *epistemic stage theory*, *epistemological belief*s, *epistemological theories*, *epistemological resources*, *epistemological knowledge, folk epistemology,* etc. These theoretical options have had a sufficient amount of time to develop and to have received critical discussion. In fact, the field has reached the point where several *PE researchers* – those individuals who study PE – have suggested it is time to reflect upon the entire enterprise and to spend some time in critically evaluating the underlying theoretical concepts.

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The central construct here is the very concept of *epistemology* and its cognate terms such as *epistemic, epistemological,* etc. Indeed, several individuals (Buehl & Alexander, 2001; Hofer, 2002, 2006; Hofer & Pintrich, 1987; Muis, Bendixen, & Haerle, 2006; Southerland, Sinatra, & Matthews, 2001) have explicitly suggested the need for this kind of conceptual reflection. For example, Buehl and Alexander (2001) say that

> …the educational literature would benefit by reexamining the source both in terms of how epistemology is discussed in the philosophical literature, as well as how the roots of epistemological beliefs emerge and are cultivated through the educational experience (p. 416).

One needs this, they claim, in order to have a sound theoretical foundation for the study of epistemological beliefs. This is because of the vague use of the term *epistemology* (2001, p. 415). Hence, if PE is going to be a well-defined area of study, the central concept of that field – epistemology – must be clearly specified. Apparently, many individuals believe this has not yet been done. If the concept *epistemology* has not been specified in a clear way, conceptual confusion may result, with a variety of pitfalls awaiting the investigator of PE. In this chapter, I discuss the concept of epistemology in relation to PE and I advance the following theses: (1) Traditional philosophical epistemology is different from PE: historically epistemology is not postmodernist; its goal, which is normative, is different from task of studying PE, which is empirical; the subfields of epistemology are briefly described and suggestions are made concerning implications for additional work in PE. (2) There are several conceptual pitfalls PE researchers are advised to avoid: the *epistemic* versus the *epistemological,* the 1st person from the 3rd person point of view, and ambiguities of *cognition*. (3) The concept of *cognitive flexibility* needs careful delineation, especially in relation to the question of domain specificity and domain generality. If the function of cognition is biological usefulness (adaptation) as the pragmatists maintain, then one can argue there is both domain-specific methods of inquiry and domain-general ones, with the domain-general ones being the testing one's ideas.

5.2 Philosophical Epistemology

Let us suppose, therefore, that such a task – the examination of the nature of epistemology – is necessary. How should this be done and who should do it? This task would seem to fall to the discipline of philosophy for two reasons. First, epistemology has been one of the main fields of philosophy for over 2,000 years going back at least to Plato (1961a, 1961b). This history has shaped the very way our intellectual heritage views epistemology as well as providing the fertile soil for various epistemological positions.

Second, it is to philosophy that one turns when issues of conceptual clarification are at stake, for it is here that the tools and methods of conceptual analysis have been developed to the greatest extent. It thus seems reasonable to turn to philosophy to clarify what *epistemology* is and should be.

5.2.1 The Epistemology of PE Researchers and Postmodernism

In the last several years, there have been important studies of epistemology by PE researchers (Buehl & Alexander, 2001; Fitzgerald & Cunningham, 2002; Muis et al., 2006; Southerland et al., 2001). Several of these articles survey the history of epistemology, at least up until the twentieth century, and provide worthwhile and illuminating accounts.

But there is something in some of these accounts that is puzzling: this is the fact that authors suddenly and quite inexplicably stop quite short when it comes to twentieth-century epistemology. One account does proceed to discuss twentieth-century European philosophy, but it skips over entirely what is arguably the richest and most developed work in epistemological thought of the twentieth-century Anglo-Saxon epistemology (what I will call *analytic epistemology*). It was, after all, this school that produced the technical and refined field of contemporary epistemology. It did the same for philosophy of science, philosophy of mind, philosophy of language (the latter two areas providing the philosophical component of what has come to be called cognitive science).

Why is there an absence of any discussion of the giants of twentieth-century analytic epistemological thought: G.E. Moore, Bertrand Russell, A.J. Ayer, Roderick Chisholm, Wilfred Sellars, C.I. Lewis, David Hamlyn, and many others? This would be comparable to a survey of twentieth-century philosophy of science that omitted a mention of Rudolph Carnap, Carl Hempel, Karl Popper, Thomas Kuhn, and so forth. No one in science education would fail to mention these individuals in discussing recent philosophy of science, the epistemology of science, and science education (see, e.g., Duschl & Hamilton, 1992; Matthews, 1994). By contrast, there is a large abyss in the discussions of philosophical epistemology by researchers in PE, in what I will call *the epistemology of PE researchers*. If researchers in PE are to have a conceptually clear and responsible account of philosophical epistemology, there needs to be a more adequate description of the field[1] along with an adequate account of the epistemology of PE researchers, for just as students have their PE, so do PE researchers. This raises the question: How adequate is the personal epistemology of PE researchers?

Individuals writing in PE sometimes have the tendency to write a revisionist history of philosophy. In several articles (e.g., Fitzgerald & Cunningham, 2002; Moore, 2002; Muis et al., 2006), it has been claimed that the history of philosophy (epistemology) took a turn toward a more European approach in the twentieth century, namely, a move toward phenomenology, existentialism, hermeneutics, structuralism, and deconstructivism. We are living, we are told, in a *postmodernist*

[1] I can't resist mentioning that in all of the PE articles I have read, there is a singular scarcity of references to standard textbooks in epistemology. Needless to say, I find this consistent absence puzzling and disquieting.

world, that philosophy has become postmodernist. Hence, if epistemology is possible, it must be a postmodernist epistemology. I have strong reservations about several of these claims for two reasons.

First, as a matter of historical fact, it is empirically false that twentieth-century philosophy has taken a postmodernist turn. This might be true of some European philosophy, but it would not be true of philosophy in general; it especially misrepresents twentieth-century Anglo-Saxon philosophy and analytic epistemology. It is often said, for example, that twentieth-century philosophy can be divided into two different philosophical approaches: Anglo-Saxon philosophy, often termed linguistic philosophy or (better) analytic philosophy and European philosophy, which is nonanalytic in its approach. Although there certainly are broad differences between these two geographical approaches, some philosophers (e.g., Dummett, 1994) have claimed there are important similarities between the two and that originally they belonged to a single source. Both contemporary philosophical schools seem fundamentally concerned with the issue of semantics, representation, and, in general, *semiotics* – the nature and interpretation of symbolic representations.

But be that as it may, it is false to characterize the current intellectual scene in English-speaking countries as being postmodernist. Philosophical thinking in England, North America, Australia, and parts of the European continent remains firmly committed to the dictates of careful conceptual analysis in all fields and, in the present context, to careful analysis of epistemological theories and concepts. To suggest otherwise would be inaccurate.

Second, from a normative point of view, the penchant among some educators and social scientists to push for postmodernism is questionable on at least two grounds. (1) Postmodernism is objectionable on general philosophical grounds (depending on how one understands this vague term) (see Burbules, 1995.). Postmodernists have not helped us on this score, since they sometimes write as if what is distinctive of postmodernist is just the rejection of modernism, which invites the query: what then is modernism? No doubt, one could make some general, sweeping statements such as postmodernism is anti-foundationalist, anti-essentialist, anti-realist, anti-representationalist, but then the reply is so are several schools in contemporary analytic philosophy. Besides, it remains unclear what these terms mean until they are more carefully explicated – something postmodernist thinkers are reluctant to do. One could also say, in a more positive vein, that postmodernism is committed to historicism, to social-constructivism, etc., but the above comments apply equally well here.

A widespread interpretation of postmodernist epistemology, at least at the hands of the critics of postmodernism, is as follows: no objective knowledge or rationality is possible since any epistemic claim is made from a particular historical and social perspective that one cannot avoid or rationally criticize. Hence, there is ultimate, unbridled diversity that cannot be rationally adjudicated. As a result, there is no hope of overcoming relativism and subjectivism. Since, according to Lyotard (1984), there is no grand meta-narrative, there is just an indefinite number of local, specific narratives. All that we can do, in Rorty's equally famous words (1979), is "to keep the conversation going." But how one can even have a conversation between radically divergent perspectives remains unclear since any conversation presupposes a common framework of language and understanding.

Some individuals (radical constructivists) have claimed that there is no objectively existing reality, that we "construct" reality, that reality is relative to our personal framework, that "everything is interpretation." This involves a misuse of the standard meaning of the term "reality," since *reality* is different from *perceived reality*. If the existence of objective reality is being denied, then such a subjective idealism has a long history of well-known criticisms and few, if any, defenders. Reality as known may involve an act of human creation or constitution, but this does not show that reality itself is a human creation.

(2) In addition, however, there are important implications of such a postmodern epistemology for the philosophy of education, which has as one of its goals the setting forth of an ideal scheme of what the goal of education should be and how it should be attained. In my opinion, a postmodern philosophy of education would be undesirable since it would claim that the goal of education should be to maximize the greatest diversity of different views and beliefs, and to soak up the feelings of such pluralism and multiplicity without a sufficient amount of critical evaluation of these different beliefs. Is it intrinsically good to have the greatest number of different views possible? Difference per se may be useful in some contexts but we still require communication and understanding between these different perspectives and this requires critical discussion. How is this possible if it all boils down to incommensurability?

For many researchers in PE, such a relativistic and subjective postmodern philosophy of education would be seen as constituting a lower stage of epistemic development than that of later stages of critical dialogical reflection. Now, of course, this begs the question of whether there is epistemological development and it would also beg the question of whether there is educational development, but most researchers in PE and philosophers of education would adhere to some conception of *development*; in this case, the only question would be how one conceptualizes its nature. In short, historically it is false that current philosophy is postmodernist; a postmodern philosophy of education is arguably inadequate and so is the postmodernist epistemology that led to it. In short, what I am claiming is that postmodernist epistemology is inadequate in general and especially when it constitutes the epistemology of PE researchers. If this is their epistemology, then I can only conclude that this is a mistaken epistemology and that another epistemology for PE is needed.

5.2.2 Positivism

Another point concerns an oft made comment about *positivism*, namely, that it assumes an objective external reality and emphasizes the need for inquirers to be objective in assessing that reality that it focuses on generalizations and cause–effect linkages, etc. (Baxter Magolda, 2004, p. 32) (see also Muis et al., 2006, p. 44). But this is not what a positivist believes.

As standardly recognized, there are at least two varieties of positivism: *classical positivism* (especially nineteenth-century positivism) and *logical positivism*. Both versions believe that knowledge, to be knowledge, must be "positive," that is, it must satisfy a high standard for what constitutes knowledge and this is related to what is *certainly* known. Individuals such as Ernst Mach, Karl Pearson, and other nineteenth-century thinkers maintained that knowledge must be limited to one's immediate experience – sensations, sense impressions, and sense data – a version of phenomenalism (Kolakowski, 1966/1968). This led some positivists to deny one could know that unobservable entities, such as atoms, exist or what their nature was. Hence, these individuals are usually said to deny realism, representationalism, correspondence, etc. This was also true of the early stages of logical positivism – the original Vienna Circle – but it was soon abandoned by its chief representatives (e.g., Schlick, Feigl, and Hempel) in the 1950s. In short, the belief that there is an objective world is not distinctive of either version of positivism.

Currently, it is indeed difficult to find serious defenders of either classical positivism or logical positivism. Both movements are basically dead as movements. But certain aspects of these views live on, remain current, and are arguably valid. A fundamental tenet of an empiricist philosophy of science is that *scientific theories require empirical testing*. Indeed, all beliefs require empirical testing – a point that John Dewey (1938) consistently made throughout his career and one that is good to remember. So much is just scientific common sense. Where a general empiricism parts company with positivism is over the question of how *certain* knowledge must be in order to be knowledge. Again, as Dewey insisted, the quest for certainty (Dewey, 1929) is a will-o-the-wisp and instead of an infallibilism, one must subscribe to a *fallibilism*, the view that none of our theories are immune from subsequent empirical testing, revision, and possibly rejection. But if one wants the best picture of what reality looks like and the best way to acquire knowledge, one should look to current science.

Insofar as PE research aims to be scientific – something most PE researchers would seem to want – it should be committed to the empirical testability of its claims. This motif of positivism (or better empiricism) is a legacy we should retain as an essential part of an adequate epistemology for PE research.

If twentieth-century philosophical epistemology cannot be labeled postmodernist, what is a preferable description of its development? Although I do not have the space to discuss twentieth-century epistemology in general, I would say that analytic epistemology went through a revolution in the middle of the twentieth century resulting in several new conceptions of knowledge and epistemology. One main motif that comes out of this would be that revolution was the rise of naturalistic epistemology (Kitcher, 1992; Kornblith, 1994). As we will see, such a view has important implications for PE research and for the conceptualization of the epistemology underlying this paradigm. Before that, however, something briefly must be said about traditional epistemology.

5.2.3 Traditional Philosophical Epistemology

Initially, it is important to see how traditional philosophical epistemology is conceptualized – at least by twentieth-century philosophers. This will provide us with a vantage point to view the epistemology of PE researchers and their conception of PE.

By *traditional philosophical epistemology*, I mean the epistemology of philosophers such as Plato, Aristotle, Bacon, Descartes, Leibniz, Locke, Berkeley, Hume, Kant, Mill, and philosophers in the twentieth century both on the Continent and in English-speaking countries. It is certainly true that such a traditional philosophical epistemology can be defined as Hofer (2002) does as the study of "the origin, nature, limits, methods, and justification of human knowledge" (p. 4). But the important point to note is that, as traditionally conceived, such an epistemology is to be done *in a purely philosophical way.* That meant that epistemology was to be a *philosophical theory of knowledge* and not a *scientific theory of knowledge*. This was explicitly set forth by Descartes, Kant, and others, and was a widely accepted view in most schools of twentieth-century philosophy. The basis of this claim rests upon several fundamental assumptions:

1. There is a sharp distinction between *necessary* truth (things that are true and have to be true, e.g., mathematical knowledge) and *contingent* truth (things that are true but do not have to be true, e.g., particular scientific facts), with philosophy providing necessary knowledge and science providing contingent knowledge
2. There is a sharp a priori–a posteriori distinction, with philosophy providing a priori knowledge (propositions that are known independently of subsequent empirical verification) and science providing a posteriori knowledge (propositions known as a consequence of subsequent empirical verification).
3. There is a sharp distinction between the *normative* and the *descriptive* (the ought and the is), with philosophy being normative and science being empirical.
4. Science must have absolutely certain, indubitable, infallible *foundations* which it itself cannot provide but which it depends upon, whereas philosophy can provide them.
5. Philosophy could do this because it employed distinctly philosophical methods (e.g., intuition, logical inference, transcendentalism, conceptual analysis, and phenomenological description), which were nonempirical in nature (Bochenski, 1965: Passmore, 1961)

In short, it was part of the historical canon that philosophy, by means of its uniquely philosophical methods, could provide *necessary,* a priori*, normative foundations* for any scientific endeavor. Hence, it could construct a completely philosophical theory of knowledge with no (or little) dependence on any scientific fact. It would follow therefore that a study of PE and the correlative concept of a *PE* would be different from this philosophical epistemology.

A further question would be whether subjects' beliefs about knowledge constitute an adequate or plausible epistemology, that is, how good an epistemology they have. Likewise, for the epistemology of the PE researcher: How good is their epistemology? To answer these questions requires a normative standard or criterion for what makes one PE epistemology better than another PE epistemology.

5.2.4 Folk Physics and Folk Epistemology

You can't do physics by investigating people's minds; you have to study the real thing

A useful analogy here might be the difference between folk sciences, for example, folk physics, folk biology, folk psychology, and the real sciences: physics, biology, and psychology. Folk (naïve) physics might be said to be the set of beliefs, possibly innate, of ordinary folk about space, time, the movement of bodies, etc. Many of these beliefs of common senses physics are, according to modern scientific physics, false. Scientific physics, on the other hand, has a *true* or truer account of the movement of bodies in space and time as well as a better conception of what the field of physics is all about, about how one proceeds to "do" physics, etc.

The contrast between physics proper and folk physics has a counterpart in the field of psychology: *folk psychology* is the naïve theory of the organism about the psychological states of others – their internal states and mechanisms, the explanation of their behavior. But psychology as a professional academic discipline may well have a quite different and conflicting account of these same items. Of course psychology studies folk psychology and attempts to explain it but few individuals would argue that professional psychology must be necessarily bound by the beliefs of folk psychology. There is every reason to think that professional psychology will take a somewhat different theoretical course than naïve psychology employing quite different methods and employing concepts at odds with folk psychology.

Now, the very same thing can be said about the field of PE and *professional epistemology.* The naïve epistemology of the average person consists of a set of beliefs, perhaps innate, about the nature of knowledge. But there is no reason to think that professional epistemology is committed to the same beliefs as folk epistemology any more than physics is committed to the beliefs of folk physics. What epistemology is really about is a technical question to be answered by professional epistemologists just as what physics is really about is a technical question to be answered by professional physicists.

So, is the PE of research subjects an epistemology? In one sense, Yes. Students and children have beliefs about knowledge, knowledge acquisition, etc. But are these beliefs epistemological beliefs? Just because they have beliefs about knowledge does not mean they have an epistemology since you can also have a folk physics that may not really be about physics (or can be an incorrect physics). Perhaps an incorrect physics can still be called physics and an incorrect epistemology an epistemology but it is important to keep the distinction between these two clearly in minds. This would perhaps be analogous to saying that skepticism was an epistemology even though it doubted whether there was anything to be called knowledge. In this sense, ordinary folk may have an "epistemology."

So the question is, do just any beliefs about knowledge constitute an epistemology or must these beliefs concern a set of questions belonging to genuine or proper epistemology? This raises the question of what constitutes a proper or genuine epistemology? One way to approach this is to list some of the major questions of epistemology. If a genuine epistemology must answer these questions (or a large number of them), then this has implications for PE research suggesting that PE research should be expanded to include the study of this more comprehensive list. PE researchers cannot expect their participants to have answers to questions until the questions have been formulated and posed to their research participants. In this way, the PE of their subjects will be a function of PE research.

5.2.5 The Major Questions of Epistemology

What, then, about the nature of philosophical epistemology? If it is important to be clear about philosophical epistemology, then an adequate characterization of the major questions of epistemology seems necessary.

Although there is no canon concerning the major questions of epistemology, I believe the following constitute an adequate listing of the major questions raised in epistemology:

1. Is knowledge possible? (the problem of skepticism)
2. Does knowledge have to be absolutely certain to be knowledge?
3. What are the sources of knowledge? Are they external to the individual or internal?
4. Rationalism versus empiricism: what are the respective roles of reason and sense experience?
5. What are the various types of knowledge, such as acquaintance, skill, and propositional knowledge?
6. What is an adequate definition of propositional knowledge? Is it justified true belief?
7. What is the nature of truth and how can we know when we have attained it?
8. What is the role of justification in knowledge and what is an adequate theory of it?
9. How can the knower attain knowledge of the external world and what is the relation between them?
10. What is the nature of a priori knowledge versus a posteriori knowledge (and the related question of the nature of the analytic–synthetic and necessary–contingent distinction)?

A quick perusal of these questions will reveal a substantial overlap with the way in which many researchers in PE view the nature of epistemology and what they study in their research subjects, in particular, items (1), (2), (3), (7), (8), and (9) are routinely covered in PE research (Fitzgerald & Cunningham, 2002). For example, the issue of skepticism (certainty, infallibility) underlies much of the work although it would be useful to distinguish *psychological (subjective) certainty* from *objective certainty*. Likewise, in studying the question of authority, one is investigating one of the sources of knowledge. But authority is just one of the traditional sources of knowledge with other candidates being faith, tradition, revelation, experience, reason, and success. Few of these candidates have been discussed in PE literature, but these possibilities seem to concern fruitful research questions to explore among young college students who often have religious views.

Other questions on this list do not lend themselves to easy empirical investigation perhaps because of their abstract and formal nature, for example, (6) is knowledge that something is the case equivalent to justified true belief? But, with a little reflection, such a question could be translated into questions comprehensible to young adults. I believe questions about the nature of truth, our knowledge of the external world, and even questions of justification are questions that are already dealt with in the research literature (e.g., King & Kitchener, 1994).

One issue rarely discussed, however, is crucial for epistemology: the issue of a priori knowledge. This is a fundamental issue in traditional epistemology and provides the backdrop to the history of modern philosophy and the debate between rationalism and empiricism. It also lies at the basis of disputes concerning the foundations of mathematics and the nature of mathematical knowledge.

It is important in students coming to understand the nature of mathematical and logical knowledge –what we can call *formal* knowledge. Formal knowledge, on the traditional view, is to be distinguished from *factual* knowledge in that it is necessarily, not contingently, true. It can be known to be true independent of experience, that is, it is a priori knowledge, not a posteriori knowledge.[2] This does not mean, as some PE researchers claim, that such knowledge is *temporally innate* but rather that one *does not need to verify it by subsequent experience*. Now, if formal knowledge is a priori knowledge, then formal knowledge is not empirical knowledge. This has important implications for the teaching and learning of mathematics and logic, something which seems to depend upon students having an adequate grasp of the concept of a priori knowledge.[3] Mathematics students may insist that mathematics is certain, but does this mean that mathematics is a priori (assuming that it is) and not true just because the social community says it is.

A similar research project could concern the developing concept of the *analytic–synthetic* distinction, so important for the history of modern epistemology but rarely

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[2] Part of the confusion about a priori knowledge is due to the several ways in which Kant uses that term. Among most epistemologists, however, the preferred view is to interpret "a priori" as meaning *independent of experience* of and not *temporally prior to experience* (*innate*).

[3] A related question of the following: assuming there is a distinction between analytic propositions and synthetic propositions, with analytic propositions being a priori, do students grasp the difference between analytic and synthetic propositions and if so, how does this comprehension develop over time? Again, I have pretty much looked in vain for studies concerning this question.

studied by psychologists and educators. This distinction was the centerpiece of Immanuel Kant's epistemology and the epistemology of the logical positivists. Propositions differ in their semantic truth value by virtue of their internal semantic structure: analytic propositions are those propositions true by virtue of the meaning of the constituent terms (e.g., bachelors are unmarried), whereas synthetic propositions are not (e.g., bachelors are tall). Kant insisted on this distinction, inherited from Leibniz, but also famously claimed there were synthetic a priori propositions, the hallmark of certain branches of mathematics and Newtonian physics. Do students have an inkling about what such matters? What, if anything, do they believe about them? If these issues are crucial to any adequate and fully comprehensive epistemology, presumably thinkers would come to have an idea concerning them: they would come to develop a conception of such a distinction. But aside from Piaget (1957) and a few others (Smith, 1993), who has studied this question?

If the above list is fairly representative of the major epistemological questions, then it seems naturally to expect that any adequate epistemology would address these (or a major part of them) and hence that PE should include them. One would suggest that PE researchers should be concerned to extend their research into some of these hitherto unexplored realms.

5.2.6 The Normativity of Epistemology

Perhaps the crucial issue in any conception of epistemology is the normative notion of *justification.* Epistemology is concerned with providing an account of the justification condition – of when a belief or action is justified (warranted, appropriate) – whereas PE is concerned with determining the actual beliefs held by subjects along (perhaps) with causal or genealogical conditions. Justification and related concepts are, at their core, normative concepts.

The term *normative* has a rather standard meaning in philosophy, which differs from how that term is used in psychology and education, where individuals speak of test norms or normative data. Here, they mean the average or typical. But this is not what philosophers mean by that term.

On the standard view, *philosophical epistemology is normative, not empirical* (just as ethics is normative not empirical); these normative fields of philosophy indicate what is correct, right, validated, appropriate, reasonable, suitable, appropriate, etc. The task of philosophical epistemology is to propose epistemic norms indicating under what circumstances an individual is entitled to form a certain belief, for example, if, under normal conditions, an individual seems to see a red light in front of him, then the individual is *prima facie* justified in forming the belief that there is a red object in front of him.

The standard or received view is that such epistemic principles, being normative, cannot be established by empirical means. To do so would be to commit the *naturalistic fallacy* of inferring a norm from a fact (or defining a norm as a fact). If this is correct, and if philosophical epistemology is a normative endeavor, then empirical research about the epistemological beliefs of students would not justify a conclusion about the normative status of such beliefs – whether they were adequate or not.

Indeed, to most philosophers in the twentieth century, the very idea of a scientific epistemology or of empirically testing epistemological views was somehow conceptually impossible, for such an epistemology would have to be constructed and evaluated by employing a posteriori (empirical) methods, whereas a philosophical epistemology was to be constructed and evaluated employing a priori (conceptual) means. It was for this reason (among others) that philosophers have not taken the genetic epistemology of Jean Piaget, for example, very seriously (Kitchener, 1986).

5.2.6.1 Justification

Justification is a concept which had its original home in religion and the law. Typically, the justification of the decision will involve an appeal to the *process* involved in decision making. This process will consist of citing the reasons one had for the decision – why a person decided the way he did. To justify one's action or judgment is to cite considerations (reasons why) that show the action or judgment was warranted, appropriate, not blameworthy, etc. These considerations explain why one did what one did and show one's action was not one to be criticized. The Oxford English Dictionary says of the word *justify* "To show (a person or action) to be just or in the right; to prove or maintain the righteousness or innocence of; to vindicate (*from* a charge), to declare free from the penalty of sin." To justify is "to do justice to" (as in punishing one for a sin committed); to make good (an argument, statement, or opinion); to confirm or support by attestation or evidence; and to corroborate, prove, and verify. To be a case of knowledge, something had to be more than a mere *belief.*

We know from the works of Plato (1961b) that knowledge is different from mere belief. Furthermore, again from Plato, knowledge is not the same as *true belief* since a belief can be accidentally true – a lucky guess –but not knowledge. What is central is that a true belief be anchored (Plato said) to the world in the right kind of way: it had to be justified, warranted, evidential, and rationally supported. This is usually known as the justification condition. A lucky guess about what number will win the lottery tomorrow is not a case of knowledge unless the guess is warranted and there seems to be no warrant if it is just a guess!

Likewise, scientific theories do not count as cases of knowledge unless they have (empirical) evidential support. So a condition such as justification seems essential for knowledge. (It turns out, however, that even justified true belief is not equivalent to knowledge.)

If one imagines that knowledge involves a belief (or cognitive state) on the one hand and something the belief is about, say, a fact or state of affairs in the world, then there must be the right kind of connection between the belief and the world in order for the belief to be true and justified. (The work of psychologists such as John

Flavell [1988] has shown that even very young children know this.) If so, then what is crucial is the right kind of interaction or relation between the knower and the known. As John Dewey (1949) and Jean Piaget (1967/1971) both insisted, knowledge is not something in the individual, nor is it something in the external world; it is a particular kind of relation between the two, hence the important concept of *relationalism* or interactionism.

Much of the current thinking in PE and folk epistemology (Kitchener, 2002) supports such a notion. Individuals appear to pass through something like an initial stage of absolutism or externalism, appealing to external authority for what is knowledge; this is followed by a stage of individualism (subjectivism) in which knowledge is inside the individual; finally, individuals reach something like a stage of interactionism or *relationalism*, in which internal and external factors have to be integrated and coordinated in the right kind of way. Knowledge and justification are neither in the individual nor in the external world but in the relation between the two. The important question for this stage and for epistemology thus concerns the connection between the individual knower and the external world.

I would add that one ordinarily justifies a belief *to* another person, *showing* him or her that such a belief is warranted, warranted by adequate (empirical) evidence, or by some other means. To provide such a rationale, one must provide reasons that another person understands and accepts or would accept under certain conditions. Justification, therefore, is essentially a social concept and originated, we may surmise, in the social arena where differences of opinion arose (For current work on social epistemology, see Schmitt, 1994.) On the contemporary epistemological scene, epistemic justification is a dominant issue currently being discussed, and PE researchers would be well to take a look at the issues of internalism versus externalism, foundationalism versus coherentism versus contextualism, etc. (Alston, 2005; Audi, 1993; Kornblith, 2001; Swinburne, 2001)

5.2.7 Claims of PE Researchers That Are Not Epistemological

As several PE researchers have already argued (e.g., Buehl & Alexander, 2001; Hofer, 2002), certain dimensions of PE epistemology do not seem to be epistemological at all: speed and control of learning, study habits, self-concept, and motivational beliefs are questions of pedagogy, learning style, etc. True, they may be related to epistemological questions in some way, but almost anything can be shown to be related to one's epistemology, for example, one's political views (conservatism versus liberalism), one's aesthetic preferences (modern art versus naturalistic art), one's attitude to self and gender, etc. A student's belief that mathematics is dull and boring or that they are bad at math will certainly influence their learning, but from an epistemological point of view, they are simply irrelevant to an epistemology of mathematics. These questions are important to curriculum design and pedagogy, but they seem incidental to real epistemology.

5.3 Some Conceptual Pitfalls

There are several conceptual distinctions it is important to observe; if not, there is a strong inclination to slide into several pitfalls. I will mention three: the distinction between epistemic and *epistemology*, the distinction between the 1st person perspective and the 3rd person perspective, a certain ambiguity in the meaning of *cognition.*

5.3.1 Epistemic Versus Epistemology

The term “epistemic” comes from *episteme,* the Greek term for knowledge (*gnosis* is another related epistemic term): what is known or the way of knowing. It typically is employed as an adjective, meaning “of or relating to knowledge” as in “an epistemic assumption.” An epistemic belief is thus a belief as related to knowledge (as opposed, say, to a moral belief or practical belief or prejudiced belief). Unfortunately, there is also an ambiguity here, since *moral belief* can mean belief related to morality or it can mean a belief that is moral. Likewise, there is an ambiguity in *scientific knowledge*: it can mean “knowledge as it relates to science” or it can mean “knowledge that is scientific.” *Epistemic belief* is subject to the same ambiguity – a belief related to knowledge or a known belief.

There is another conceptual issue here. A belief is often taken to be a representation *about* or *of* something. Hence, “epistemic belief” can sometimes mean “a belief about knowledge,” where the belief is a representation of knowledge. Since a representation operates at a higher level than the thing represented, a belief would be on a meta-level compared to knowledge. These levels can be represented in the following way (Fig. 5.1)

The term *epistemology* is the theory of the epistemic, *logos* being translated as “theory of, account of, or discourse about.” The logos part is at a higher level than the epistemic part since it is about the latter. So, assuming that there is knowledge, an account of it would be an epistemology. One could also call it an epistemic belief (a belief about the epistemic). If this is correct, then epistemic belief would be equivalent to epistemology.

But what then would be an epistem*ological* belief? It would be a belief about epistemology. If one believes that all knowledge is innate, this would be a belief as it relates to the theory of knowledge and would be roughly equivalent to epistemic belief (a belief about knowledge). But an epistemological belief might belong to still a higher level, a representation about epistemology (not the epistemic). Here, such a belief would not be about the nature of knowledge but about the nature of epistemology, for example, that epistemology can become a science. This can be called meta-epistemology.

I admit that all of this is extremely confusing and difficult to keep separate, but the point worth making is this: one needs to be clear about the meaning of notions

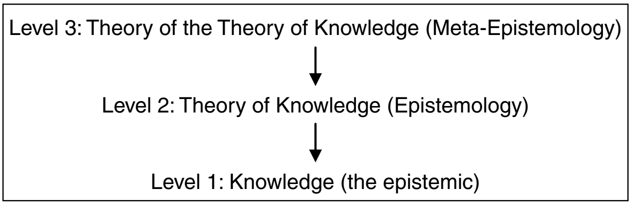

Fig. 5.1 Various levels in the theory of knowledge

like *epistemic* belief versus *epistemological* belief. Some authors use the former, whereas others use the latter. Are they employing the same concept or not? Things get even more confusing when one reads about *meta-epistemic* beliefs or *meta-epistemological* beliefs, *epistemology*, and *epistemological* knowledge. In short, authors need to specify more clearly what they have in mind when they use these terms.

One example of this confusion can be found running throughout the PE literature. One often reads about *epistemic development* and *epistemological development*. Are these the same concept? No. Epistemic development refers to the development of knowledge – what is known. Most individuals would agree, for example, that there has been an increase in scientific knowledge over the years.

This is epistemic development. Likewise, following Piaget and others, one can claim that in ontogenesis, there is an increase in knowledge from childhood to adulthood. But again, this is epistemic development.

This is different, however, from epistemological development. Throughout the history of science, various scientists, for example, have proposed accounts about the theory of scientific knowledge. Suppose we were to set forth a temporal sequence of these epistemologies (Laudan, 1968; Losee, 2001), and suppose we claim that there is a sequence (e.g., deductivism, inductivism, and hypothetico-deductivism), which constitutes the actual epistemologies advanced in the history of science. Has there been an epistemological development in moving from, say, a purely inductivist approach to a hypothetico-deductive approach, or from a realism to an instrumentalism? If so, there would be epistemological development.

Likewise, in the case of the individual knower, epistemological development would be a progressive increase in the person's theories of knowledge, not just in his knowledge. Is there epistemic development in the individual? It certainly seems so. Is there epistemological development in the individual? That is a quite different question, a subject for PE.

This point is closely related to the question of what Piaget's genetic epistemology is all about (Kitchener, 1986). Piaget studied the epistemic development of the individual, which Piaget called the *epistemic subject* (Piaget's term). Over time, from infancy to adulthood, the knowledge of the epistemic subject develops and improves as the subject interacts with its environment.

But genetic epistemology is Piaget's theory about this epistemic development. His genetic epistemology is a proposed explanation of a complex set of data concerning the epistemic growth of knowledge in the individual. His particular account – his genetic epistemology – might be wrong and yet it might still be true that there was epistemic development. Piaget said very little (if anything) about the development of the individual's theory of knowledge – what could be called *the epistemological subject*. But this would have been a different question from that of explaining how knowledge develops in the epistemic subject. Piaget had relatively little to say about childhood epistemology, folk epistemology, or PE in a systematic way although his early work on different socio-cognitive perspectives is relevant here (Kitchener, 2008).

In contrast to Piaget's study of epistemic development, others (e.g., King & Kitchener, 1994) studied epistemological development – how theories of knowledge change over time. In the same way, Kohlberg studied moral development in the individual; he did not study the development of moral epistemology in the individual in any kind of systematic way.

5.3.2 1st Person Versus 3rd Person Points of View

As my previous comments have pointed out, it is important to keep clear the difference between a 1st person point of view or perspective and a 3rd person account. Psychologists study individual subjects who presumably have knowledge and beliefs about knowledge. Data are collected about their understanding or representations of things including representations of knowledge. This constitutes the realm of phenomena to be explained (the *explananda*). PE research belongs here, since the object of study, the 3rd person realm, is the realm of the other. Scientists can talk about, say, the epistemic development of subjects. But these would be 1st person theories about the 3rd person theories of knowledge.

One of the most interesting features of this area of study is the following kind of self-referential or circular property of this endeavor: the 3rd person point of view has become the 1st person point of view. Let me explain.

PE researchers studying the PE of students were themselves once subjects in this population. They were once students who later become professors. Hence, they too once held a certain PE at a certain age and now also hold a PE. Is their current PE different from their earlier PE? Is their PE different from the PE of their subjects? Suppose there are stages of PE development, for example, absolutism, relativism, and critical evaluation. Can the PE researcher progress beyond this last and highest stage or have they become fixated at a lower stage? Have they constructed an epistemology quite different from the PE of any of their subjects? Should other PE researchers be studying the PE of this researcher? If so, what would it show?

Of course, if one rejects a stage theory of development, one need not draw this conclusion. But one needs some kind of developmental norm or metric to evaluate students. It might be a single variable or it might be several variables. But one needs some kind of developmental vector signaling progress or improvement; otherwise, how would one determine if the student has learned anything? Educators have to make value judgments about the performance of students. Although stage theories are not currently *de rigueur*, there need to be alternative models proposed, tested, revised, and elaborated. Currently, there are not many such alternatives.

There are two points here. First, by looking and hopefully explaining the PE development of their subjects, PE researchers are (presumably) explaining their own PE development. Second, this self-referential phenomenon has normative implications. Suppose, for example, there were stages of epistemological development: S_1 S_2 S_3. Suppose that the PE of the PE researcher were S_2. Then it would seem to follow that the PE researcher is at a lower stage of PE development than those subjects whose PE is S_3. If a stage theory of PE development allows one to make normative judgments about college students, this stage theory allows a normative judgment to be made of the PE researcher. Presumably, we want our teachers to foster student development culminating in S_3. If so, then our teachers also need to be at S_3 or higher.

5.3.3 The Nature of Cognition

A third pitfall that should be avoided concerns the very concept of *belief* or *cognition* (as opposed to *knowledge*). Many social scientists have the mistaken tendency of equating *knowledge* with *belief* or *cognition.* This is due, in large part, to the ambiguity and vagueness of these terms, especially *cognition.* Sometimes it is used so as to denote the knowledge of an individual but at other times it is not.

Some cognitivists equate cognition and knowledge. For example, the cognitive psychologist, Ulrich Neisser (1976) says: "Cognition is the activity of knowing; the acquisition organization, and use of knowledge" (p. 1). Kruglanski (1989) lapses into the same mistake of equating cognition and knowledge.

Sometimes this mistake takes the form of equating belief with knowledge. For example, the sociologist of science David Bloor (1991) says: "Knowledge for the sociologist is whatever people take to be knowledge. It consists of those beliefs which people confidently hold to and live by" (p. 5). He goes on to say

> Of course knowledge must be distinguished from mere belief. This can be done by reserving the word 'knowledge' for what is collectively endorsed, leaving the individual and the idiosyncratic to count as mere belief (p. 5).

On this account, *knowledge* is *collective beliefs*.

"Cognition" is unfortunately ambiguous as between "a mere representation" and "knowledge." One can be aware or cognizant of something and yet that something may not exist since there are false representations (false cognitions), which is to say the content of your cognition (e.g., an afterimage, a hallucination) does not exist in reality.

When a PE researcher says someone has an epistemic cognition or an epistemic belief, what does he mean? What is he presupposing? Is a cognition about the epistemic different from a belief about the epistemic in that the former case the PE researcher would be presupposing that the individual's cognition was a case of knowledge, whereas in the latter case, she would not? Is she presupposing that the epistemic cognition is true, that the individual's epistemology is correct? What this points to, I think, is that it is important to be clear about what our words mean and what we are assuming when we ascribe mental states to others. *Cognition* is a very slippery word.

5.4 Cognitive Flexibility and Epistemology

Individuals must adapt to their world and thus solve a basic set of problems: how to find food and a mate, rear children, provide for their education, select a career, pass on important cultural values and preserve their traditions in a rapidly changing world, assimilate the latest technology, etc. We may assume, therefore, that their environment is not a static one but a dynamically changing one, presenting an open-ended set of problems to be solved and questions to be answered.

We may also assume that cognition originally arose as a biological tool to assist organism in these complex problem-solving tasks. Hence, the biological function of cognition is to facilitate the adaptation of the organism to its environment by means of being able to solve problems. As the pragmatists have always insisted, *ideas are instruments of action*, tools to assist us in problem solving. Pragmatic success is essentially tied to truth and the value of knowledge, and hence traditional epistemology must become an evolutionary epistemology (Dewey, 1910).

The resources necessary for accomplishing these problem-solving tasks may be sparse in number or power. The problems may be well structured, with a definite answer to be found in a short period of time, or ill-structured, in which case it may be impossible to generate a conclusive and certain answer to such questions. The most that may be hoped for might thus be probabilistic answers, tentative answers that may always be tested and questioned (if the need arises).

Problem solving is thus a goal-directed enterprise (Newell & Simon, 1972), one requiring the construction of hypothetical solutions – ones to be tested by implementing them in action and then determining if they take one closer to the goal. If so, some progress has been made; if not, one proceeds to construct different conjectures and then tests them.

Problem solving thus involves strategies and heuristics as well as algorithms, all of these constituting a set of procedures for problem solving. Some strategies have, over time, proven their mettle and are temporarily retained, being useful for solving problems. Many of these find their way into one's culture and intellectual traditions and become part of our received wisdom or common sense.

Clearly, problems arise in a specific context or situation, particular solutions that works in one context may not work in another. Hence, problem solving requires the ability to be sensitive to the particular constraints of a problem context and this in turn requires an attitude of flexibility and open-mindedness coupled with the creative ability of inventing new ways to solve problems. In short, problem solving is domain specific and contextual, something pragmatists have always insisted upon.

But on the other hand, pragmatists such as John Dewey have also insisted on the domain generality of some methods, in particular, those methods that have proved most successful in science and these essentially involve *testing one's ideas* (an old-fashion empiricist theme). This involves the hypothetico-deductive method, the method of science but also the method of common sense (Dewey, 1938). If cognition is essentially problem solving, then it must be evaluated in terms of its actual ability to solve problems and this must involve testing our ideas to see if they increase our path a solution. Intelligence in the modern world, Dewey insisted, thus involves the best methods of hypothesis testing and these are to be found in science. We can take Dewey's point to be that there are thus domain-general methods for acquiring and validating knowledge.

For Dewey and other pragmatists, therefore, an adequate epistemology for the modern world is one in which these domain-general procedures are applied to the unique particularity of various contexts and situations. Cognitive flexibility is thus the intelligence to use those procedures that have worked in the past, to invent new procedures when old ones have failed, to tailor these to different contexts, all of this to be tested by the method of science. We thus have room both for domain specificity and domain generality, a point that individuals who first introduced this distinction (e.g., Fodor, 1983) have also claimed. If this is correct, then we need to be teaching students the value of domain-general method(s) as well as the ability to be sensitive to the peculiar requirements of varying contexts.

A person's beliefs about cognitive flexibility have an important bearing on problem-solving efficacy. On the one hand, if it is part of one's PE to believe in the absolute certainty and infallibility of epistemic sources such as an external authority (e.g., a scientific expert and a textbook), one may well fail to succeed in a problem-solving task if such an authority does not deliver the goods. One may, then, simply give up in despair and cease trying to solve the problem, believing "if the authorities can solve the problem, then it is insoluble." Success will not be forthcoming. On the other hand, if one is a relativist or subjectivist about cognitive diversity, believing that "anything goes" and one idea is just as good as any other idea, this person will also be frustrated in his or her attempts to solve a problem, for if the individual doesn't test this plethora of different ideas, he or she will not hit upon a successful one. In short, the early stages of epistemological development will not allow the individual to succeed. Success at problem solving is the motor that drives development.

It appears to be the case that it is only something like a combination of both of these approaches, found at later stages, that will prove to be successful: one must initially be willing to entertain a variety of possible solutions, some perhaps appearing very implausible, followed by a testing mechanism that eventually will succeed (if anything does). The testing method, Dewey's hypothetico-deductive method, is such a testing method, leading to the rejection of hypotheses that fail, and tentative acceptance of those hypotheses that succeed. One has, therefore, an initial pluralism together with a unitary method of selection.

For many individuals such as Dewey and Karl Popper (1963), this method of conjectures and refutations (or blind variation and selective retention) is the method of scientific inference and it is also the method of problem solving. For Dewey, Popper, Campbell, and others, it is the method of natural selection applicable to the cognitive arena of ideas. It is also a model to be found among several accounts of the development of PE.

It should also be pointed out that such a method of problem solving has been postulated to be the "motor of development," that mechanism that underlies and explains the course of developments from earlier, less adequate stages to later, more adequate stages. What explains the motor of development is, in short, problem-solving power: individuals move on to later epistemological stages because of the necessity to solve problems and later epistemological stages can be said to have greater problem solving power than earlier ones. Such a view (or something like it) can be found, of course, in Piaget (1975/1985), Kohlberg (1981) and many others. I am suggesting it can also be found running throughout the course of epistemological development.

5.5 The Challenge of Naturalistic Epistemology

Throughout this chapter, I have presented what is called the standard or received view of epistemology. It is the view of epistemology (and philosophy) that is part of the traditional canon of philosophy, the more or less official view of the nature of epistemology, its subject matter, methods, and results. Throughout most of the twentieth century, this view was the standard or traditional one, the cornerstone of analytic epistemology.

All of this was to change, at least in Anglo-Saxon countries, in the 1960s. There was a revolution that occurred in epistemology (and philosophy in general) with the rise of naturalistic philosophy. This new naturalism resulted in a naturalistic epistemology, philosophy of science, metaphysics, semantics, and ethics. The ramifications of this new turn in philosophy has yet to be fully realized and explored and I can only say a few things about the particular field of naturalistic epistemology and how it relates to the question of research and theorizing in PE.

Unfortunately, I must be brief, but there are systematic and comprehensive discussions of this new school of thought (Kitcher, 1992; Kornblith, 1994; Maffie, 1990). Naturalistic epistemology arose in the 1960s largely at the hands of W.V.O. Quine (1969) who believed traditional epistemology was inadequate and needed to be supplemented by a naturalistic account or that the entire project of traditional epistemology was misconceived. Although I do not have the space to discuss the problematique that generated naturalistic epistemology, let me say that it was, in general, the failure of traditional epistemology to solve epistemological problems that lie at the root of the reason. Naturalistic epistemologists believe a more scientific account, one based upon science, was a more fruitful way to proceed.

A useful way to view naturalistic epistemology in contrast to traditional epistemology is to indicate the former's views about the several points I mentioned as being more or less constitutive of traditional epistemology. According to naturalistic epistemology:

1. There is no sharp distinction between *necessary* truth and *contingent* truth. There may be a distinction between the two or such a distinction may be denied (in which case all knowledge is contingent). In any case, there is no reason to think that philosophy delivers necessary truth whereas science does not.
2. There is no sharp a priori–a posteriori distinction, in fact there may be no distinction at all in which case all knowledge can be seen as a posteriori (empirical). If there is such a distinction, it is one of degree, not of kind. In this case, epistemology is continuous with science.
3. There is no sharp distinction between the *normative* and the *descriptive*. They may be continuous or the normative may be reducible to, identical to, or definable in terms of the empirical.
4. Science need not have absolutely certain, indubitable, infallible *foundations*; on the contrary, science is committed to fallibilism, probability, and likelihood. If it needs foundations, these would be weak foundations and it would, in any case, not fall to philosophy to provide such support.
5. Philosophy does not have distinctly philosophical methods (e.g., intuition, logical inference, transcendental method, conceptual analysis, and phenomenological description), which were nonempirical in nature. All of these alleged methods either contain empirical components or are questionable on empirical grounds (Kitchener, forthcoming). Hence, all intellectual methods are empirical in some sense and to some degree.

It follows, therefore, that there is no hegemony of philosophy compared to science. Science does have to await conceptual clarification from philosophy.

With respect to the question of justification and normativity, naturalistic epistemologists differ, but one main line of thought maintains that justification is inherently normative, normativity is central to epistemology, but there can be a scientific (naturalistic, empirical) analysis of the normative component of justification.

If this is correct, then it would seem to follow that one can investigate true epistemology in a scientific (*naturalistic*) *way.* Hence PE research could, in principle, discover the folk epistemology of young adults and children. To do so, however, it would have to reconsider and reconceptualize many of the assumptions and claims it makes. But in principle, this would be possible and hence one could empirically discover the underlying epistemologies of the average person. The result would be that PE research would no longer be seen as an ordinary psychology or educational pedagogy but an investigation into an empirical epistemology.

On the other hand, PE research could, in principle, produce results that would be of value in epistemologists working in a more philosophical tradition. For naturalistic epistemology, the empirical and theoretical results of science constitute the ultimate data for any adequate epistemology. Hence, a "philosophical" epistemology would be revisable if, say, empirical evidence required such revision. We already have examples of this line of influence operating in the case of the genetic epistemology of Jean Piaget (Kitchener, 1986). This has been continued by researchers such as Kitchener and King (King & Kitchener, 1994), whose longitudinal and theoretical study of the development of reflective judgment is a case study of the development of epistemologies in adolescents and young adults. Several other PE researchers (as well researchers in the folk epistemology of children) have made similar contributions.

5.6 Conclusion

I have taken a philosophical perspective for viewing the recent exciting and interesting work on PE. There was a time when philosophers would not have believed there was a field called PE or that it would be pursued by scholars outside of their field. Philosophers have recently been learning the lesson that philosophy cannot be done in splendid isolation from the rest of the scholarly (scientific) community. This has meant that there is much research that has been and is being done in the behavioral and social sciences that is relevant to what they are interested in. No longer can they remain exclusively in their armchair oblivious to empirical knowledge. Although many of them still do not take the work of scientists seriously enough, I am not one of them. I take the work of individuals doing PE research very seriously since it is a field that sets out to answer the question: what is the epistemology, the actual epistemology, of the population of individuals we teach? Such a field has a great deal of relevance to how teachers of philosophy should engage in the activity of imparting knowledge: PE research has important implications for good pedagogy in philosophical instruction. It also has important curricular implications for philosophy departments since we ought to construct our curriculum based upon the best knowledge of the psychology of college students, how they learn, and what they are capable of learning. It is for this reason that I have been skeptical of the teaching philosophy to children movement in philosophy (Kitchener, 1991). Children cannot do philosophy the way philosophers would like. But college students also cannot do certain kinds of things that philosophers have as their pedagogical goals (King & Kitchener, 1994).

On the other hand, I think it is also important for PE researchers to be up to date on what their contemporary philosophical epistemologists are saying about epistemology. As I have indicated, if one is going to be clear about what a field of endeavor is, one should at least initially consult the experts in that field. One can argue for a departure from that common conception at a later date. There has been a tendency on the part of some social scientists to ignore what epistemologists think about epistemology and to proceed to introduce their own conception. They are, of course, free to do this, but at a price, a conceptual price. They may wind up with a conception of epistemology that is really not epistemology at all but something else – a study of the students beliefs not about knowledge but about a quite different field, for example, their frustration with big lecture classes. The personal epistemology of, say, college students must be a theory of knowledge and what this means is set forth in numerous works in epistemology. But that is the price I am afraid of getting clearer about the domain of epistemology. In this chapter, I have tried to point out some of the important aspects of epistemology I think is worthwhile to make in the hope of contributing to a better conceptual understanding of epistemology and, hence, indirectly of personal epistemology.

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Chapter 6
Beliefs About Abilities and Epistemic Beliefs: Aspects of Cognitive Flexibility in Information-Rich Environments

Dorothe Kienhues and Rainer Bromme

6.1 Introduction

In this chapter, we discuss the challenge for members of our information society to process the vast amount of easily accessible (scientific) information in information-rich environments, such as the Internet. We outline that because information accessed through the Internet is often inconsistent or conflicting, recipients are forced to find an adequate explanation for the inconsistencies at hand. In our view, cognitive flexibility, when processing ill-structured content, such as inconsistent and conflicting scientific information, does not just imply representing knowledge from different perspectives (Coulson, Feltovich, & Spiro, 1997) or restructuring one's knowledge due to changing situational demands, for example, complex learning material (Spiro & Jehng, 1990). We assert that the construct also connotes flexibility in adjusting different possible explanations for experiencing uncertainties in scientific knowledge. To determine laypersons' flexible and critical reception of scientific information, we will focus on two possible sources of uncertainty: people can assign occurring inconsistencies to their own lack of ability to understand the information ("ability explanation"),or they can conclude from these inconsistencies that knowledge about the topic at hand is in itself inconsistent, developing or uncertain ("epistemic explanation"). To be able to distinguish between these two possible explanations, people must have a realistic view of their own competencies, that is, adequate beliefs about their abilities (statement 1). Furthermore, they should have a realistic view of the boundaries of scientific knowledge, that is, adequate epistemic beliefs (statement 2). In other words, cognitive flexibility in information-rich environments (as defined above) requires both kinds of beliefs to find the most suitable explanation for the inconsistencies people notice in scientific knowledge.

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Nevertheless, we acknowledge that people's decision about how to attribute conflicts between information can also be less black and white. Rather, a mixture of both aspects is also a possible explanation.

Within the scope of searching for scientific information on the Internet, the empirical investigation of when and how people refer to ability and epistemic explanations for (conflicting) knowledge claims is possible (statement 3). Besides contributing to the question of the role of epistemic beliefs and beliefs about abilities in information-rich environments, the results of such research might have implications for a long-lasting controversy within research on epistemic beliefs. While some researchers subsume beliefs about abilities to learn and to know under the concept of epistemic beliefs, others insist on a clear conceptual distinction between what they believe to be epistemic beliefs and beliefs about abilities.

In this chapter, we first outline the demands of information-rich environments and then suggest that the process of encountering scientific information on the Internet might be a test bed for investigating the relationship between epistemic beliefs and beliefs about abilities. In the next section, we delineate the role of beliefs about abilities in processing scientific information (cf. statement 1). We then sketch the role of epistemic beliefs when people process scientific information (cf. statement 2). Subsequently, several studies we have conducted are introduced that explain how to empirically manage the role of epistemic beliefs and beliefs about abilities in information-rich environments (cf. statement 3). We conclude that for an adaptive and flexible response to the different situational demands of information-rich environments, both beliefs about abilities and epistemic beliefs are important. In the last section of this chapter, the ongoing debate on the conceptualization of epistemic beliefs is particularized, highlighting that the results of our studies indicate the value of separate research into beliefs about abilities and what we believe to be at the heart of epistemic beliefs.

6.2 The Demands of Information-Rich Environments: The Burden of Easy Accessibility of Scientific Information

Modern information technologies have greatly contributed to the information-rich environments of our times. The Internet especially provides new opportunities for accessing information and for knowledge exchange. The amount of information available on the Internet has grown enormously during the last decade, and searching the Internet for information offers convenient access to an enormous amount of information. Accordingly, Weare and Lin (2000) referred to the Internet as surely the richest seam of information in the history of civilization. However, the access to vast amounts of information in information-rich environments places some demands on its recipient, as it leads to a continuously expanding need to possess not only basic scientific knowledge but also, and in particular, an understanding of the sciences, of how they work, as well as of their potentials and limitations (e.g., Driver, Newton, & Osborne, 2000; Sadler, 2004).

A special challenge in information-rich environments is the exposure to scientific evidence that is provisional, contradictory, or controversial. Such internal uncertainty is a normal feature of scientific knowledge; it characterizes everyday routines in the empirical sciences but is most often in sharp contrast to the public expectation of science. The open access to science-based information on the Internet permits access to scientific information that mirrors such internal uncertainties (Eysenbach, 2003). Inconsistencies or uncertainties within science can be traced back to multiple reasons. First, methodological problems in the studies conducted might be the reason (Fugelsang, Stein, Green, & Dunbar, 2004). In addition, incoherences in the terminology used, insufficient sampling techniques (Peel, 2005), or uncertainties in differentiating between causal relations and spurious relations (Waldmann & Hagmayer, 2005) are possible explanations. Moreover, inconsistencies can also reveal "real" contradictory knowledge claims. For example, several health issues such as cholesterol are controversially discussed in the medical literature (Dale, Coleman, Henyan, Kluger, & White, 2006). The exposure to inconsistent and potentially contradictory scientific evidence puts heavy demands on its recipients. They have to assess whether the evidence is inconsistent or even contradictory, and they have to find an explanation for the inconsistencies or contradictions they experience.

6.3 Antecedents for Adequately Dealing with Information on the Internet

In information-rich environments such as the Internet, laypersons can easily access scientific or science-based information. The easy access to information is accompanied by an increased accessibility of inconsistent or contradictory information, which information recipients must effectively process for a successful and productive use of the Internet.

When information recipients encounter inconsistent information, they usually have to draw by some means a coherent conclusion from incoherent information because of contradictory "information bits." This processing includes the necessity to decide from where the inconsistencies originate.

The notion that people try to find an explanation for inconsistencies can partly be traced to attribution theory, which focuses on the types of causal explanations people make. As Kelley states in his classic article (1973), attribution theory deals with the information people use "in making causal inferences, and with what they do with this information to answer causal questions" (p. 107).[1]

[1] However, it is important to note that attribution theory as it is part of research on social cognition (e.g., Heider, 1958) focuses on explaining the causes of behavior of oneself and of others (self-perception, social perception, cf. Kelley, 1973). Such aspects of attribution theory will not be part of our further deliberations.

Both empirical studies and theoretical work exemplify that people explain inconsistencies in information in different ways. For example, Otero (2002) analyzed students' comprehension, monitoring when reading science texts which entailed contradictions. These contradictions decreased understandability. Otero (2002) provided two possible explanations for the perceived lack of understandability. On the one hand, people may believe in an objective problem and assume that the comprehension problem cannot be solved because an inference that would solve the problem is unlikely to exist. On the other hand, people might believe that they are unable to make the necessary inference and thereby solve the comprehension, but other people with more knowledge would succeed in comprehending the text. Otero (2002) assumed that both general and specific knowledge will influence this decision. In another study, secondary school students read science texts containing contradictions and then judged the understandability of these texts (Otero & Campanario, 1990). Results revealed that several participants thought that they were not familiar enough with the subject of a scientific text, and, therefore, did not identify the contradictions within the science texts provided. Otero and Campanario (1990) suggested that because of their lack of knowledge, several students thought that the contradiction could be "explained away in terms unknown to them" (p. 452) and that someone more knowledgeable would be able to achieve a coherent understanding. Therefore, the students conceptualized the poor comprehensibility of the texts as a subjective problem, ascribing it to their poor knowledge, but not to inconsistencies in the texts provided. Furthermore, Karabenick (1996), although his study focused on social influences on comprehension monitoring, purported that when co-learners signal that they do not comprehend a text, participants might either attribute the lack of understanding to the difficulty of the text or to the co-learner's ability or motivation.

We conclude from the work outlined so far that people might have difficulties in finding an appropriate explanation for contradictions within texts. Otero's work (Otero, 2002; Otero & Campanario, 1990), however, is based on a classic error detection paradigm where people read manipulated single texts that contain contradictions, which are violations against standards of coherence.

The following studies that we outline refer to the explanation that contradictions might also occur because knowledge about a specific topic is in itself contradictory, uncertain, or developing. Baxter Magolda (2002) introduced a college sophomore who regards himself as insufficiently knowledgeable, and therefore trusts the author whenever he is confronted with discrepancies in his studies. This circumstance indicates that the learner does not consider the possibility that the knowledge he processes is in itself contradictory. She described that the sophomore student changes his view over the years in college, and that he exhibits self-authorship years later when interviewed again, as he then sees knowledge as "constructed by persons with appropriate expertise" (p. 89). Similarly, the sociologist Renée Fox (1957) suggested that two types of uncertainty exist in physicians' decision making. One type is substantiated in the "[…] incomplete or imperfect mastery of available knowledge. No one can have at his command all skills and all knowledge of the lore of medicine" (p. 208). The second type of uncertainty results from limitations in current (medical) knowledge. Fox (1957) concluded that these two sources of uncertainty lead to a third source of uncertainty, which refers to the difficulty in distinguishing between the two uncertainty sources, between "personal ignorance or ineptitude and the limitations of present medical knowledge" (p. 208 f).

We argued above that information recipients must decide from where inconsistencies originate when they encounter inconsistent information. Based on the research represented thus far, we argue for two different explanations for inconsistencies. One explanation is that people are unable to make a necessary inference, and they do not have the ability to gain understanding. Other people, however, with more knowledge would succeed (ability explanation). In contrast, the other explanation is that people conclude from inconsistencies or contradictions that knowledge about the topic at hand is in itself inconsistent, developing, or uncertain because of the limitations in knowledge about the problem at hand. In this case, inconsistencies are inherent to the discipline or topic (epistemic explanation). Beliefs about one's abilities play a role in the former explanation (Otero, 2002), while epistemic beliefs are important in the latter (Bråten, Strømsø, & Samuelstuen, 2005; Hofer, 2004). That is, people should be able to consider the possibility that the information displayed on the different Internet pages *is* conflicting and preliminary, and that the information does not only *appear* to be that way because they are not able to bridge the gap of understanding.

We propose that a distinction between the two explanations is crucial for laypersons' flexible and critical reception of scientific information. Such a distinction between epistemic and ability explanations is part of the problem solution when one encounters inconsistent or conflicting information, and it is an important self-regulatory competence. For example, how people attribute a contradiction at hand will result in different behavioral consequences (e.g., giving up, asking someone who knows). To be able to distinguish between these two explanations, people must have a realistic view of their own competencies and be able to adequately judge their abilities to understand the contradiction (adequate beliefs about abilities). Furthermore, they must hold a realistic view of the boundaries of scientific knowledge (adequate epistemic beliefs).

6.4 On the Role of Beliefs About Abilities in Dealing with Scientific Information

We claim that finding an explanation for contradictions between information (e.g., on the Internet) requires a self-assessment of one's own abilities to make sense of the information at hand. How individuals appraise their abilities is a topic of increased research interest within psychology since the cognitive revolution in the 1970s and 1980s (Baumeister, 1999). The appraisal of one's abilities (e.g., problem-solving skills) has been widely accepted and empirically shown to be an important predictor variable of how a person approaches challenges and acts in a specific situation.

Various studies have emphasized the role of perceived ability and related constructs as mediators of behavior, especially in self-regulated learning (Bandura, 1997; Eccles & Wigfield, 2002). A critical and appropriate appraisal of one's capacities to process the information at hand is a prerequisite for a flexible adjustment to the demands of a learning task.

When laypeople consider scientific information, they may or may not feel capable of understanding the information accessed. Both an overestimation of one's level of comprehension ("illusion of knowing," e.g., Anderson & Beal, 1995) and an underestimation of comprehension are detrimental, because they hinder effective learning (Karabenick, 1996). Comprehension monitoring is influenced by factors such as goal orientation (Kroll & Ford, 1992) and by beliefs about abilities. Various motivational theories (Bandura, 1997; Eccles, Wigfield, & Schiefele, 1998; Wigfield & Eccles, 2000) described the impact of the interplay between goals and beliefs about abilities on the motivation to stay with a task, even if it is difficult. Persistence is based on stable beliefs about abilities and also on the situation and task-specific assessment of the ability to cope with a concrete task. Such overarching, stable beliefs about abilities have been described in research on everyday conceptions of intelligence (as beliefs about abilities) and their effect on goal choice. Dweck (1999) outlines two entirely different trait-like beliefs about abilities. One is to view intelligence as a fixed trait that one possesses to a certain degree (the entity theory of intelligence), the other is to portray intelligence as something one can increase through effort, for example, through learning (incremental theory of intelligence). Goal choice (performance or mastery goal) is motivated by the view people hold of their abilities, either an incremental view or an entity view (Dweck & Leggett, 1988).

A more task-specific account on self-perceived ability is Bandura's self-efficacy theory. Bandura (1997) defined self-efficacy as "beliefs in one's capabilities to organize and execute the course of action required to produce given attainments" (p. 3). That is, the concept of self-efficacy refers to valuing of the self in specifically defined situations. The definition makes clear that self-efficacy "is concerned not with the skills one has but with judgments of what one can do with whatever skills one possesses" (Bandura, 1986, p. 391). Self-efficacy is hypothesized to influence effort expenditure, persistence, and achievement. In general, self-efficacy beliefs influence self-regulation on different layers (Bandura, 1986). For example, higher self-efficacy implies loftier goals in a specific achievement domain, while lower self-efficacy leads to setting lower goals. In addition, self-efficacy also influences the choice of activities, in a way that people preferably engage in activities within their capabilities, and tend to avoid activities they do not feel capable of handling. Moreover, self-efficacy influences the effort and persistence shown in goal-directed activities, especially when encountering obstacles. That is, stronger perceived self-efficacy means more persistent and vigorous expenditure, and it also influences both the efficacy and the effectiveness of problem solving. Conversely, people with low perceived self-efficacy tend to reflect on personal deficiencies, which can lessen the attention on the demands of a situation and undermine the effective use of cognitive resources.

Beliefs about abilities are also addressed within the expectancy portion of the (modern) expectancy-value theory, which emphasizes achievement-related choices (e.g., Wigfield & Eccles, 2000). Wigfield and Eccles (2000) define beliefs about abilities as "the individual's perceptions of his or her current competence at a given activity" (p. 70, in reference to Eccles, Adler, Futterman, Goff, Kaczala, Meece, & Midgley, 1983), that means in this model "ability beliefs are conceived as broad beliefs about the competence in a given domain, in contrast to one's expectancies for success on a specific upcoming task" (Eccles & Wigfield, 2002, p. 119). According to the expectancy-value theory, expectancies are based on such broad beliefs, but they are then influenced by task-specific beliefs, such as perceived difficulty of a task or the perception of individual's goals.

The conclusion can be drawn from the theories presented thus far that subjective explanations for difficulties of understanding (as they could occur because of conflicting information) are relevant for motivation and persistency of learning. Moreover, the theories agree in differentiating between more or less stable beliefs about abilities and task-specific beliefs held by a learner. The theories focus on the role of beliefs about abilities in the accomplishment of an action. Therefore, research on the impact of beliefs about abilities on processing conflicting scientific information should consider when and how such beliefs impact the *process* of understanding conflicting information.

Few studies outline the important role of beliefs about abilities in processing complex written scientific information. For example, Bendixen and Hartley (2003) presented multiple texts about former Yugoslavia in a hypertext system, including discussions from sometimes opposing experts. They measured, among other variables, participants' beliefs about fixed ability (which can be traced to Dweck's (1999) two different mindsets described above) and administered a learning test after dealing with the hypertext. They found that participants who believed less in fixed ability performed better in the learning test. Participants who believed more in fixed ability made less effort to finally understand the information provided. For example, they did not use the additional hypermedia tools available. Bendixen, Dunkle, and Schraw (1994) found that the belief in fixed ability (see above) was the best discriminator for how people responded to the question if truth is unchanging. They concluded that "those who view ability as fixed may be less inclined to pursue challenging academic experiences or tackle intellectual tasks strategically and may be less inclined to develop and utilize sophisticated reasoning skills when thinking about ill-defined dilemmas" (p. 1599). Therefore, one can assume that people who believe in fixed ability might have less sophisticated skills to properly process conflicting information on the Internet.

Schommer (1990) asked participants to read a scientific text passage (on four plausible theories of aggression) in which the concluding paragraph was removed. Participants were then asked to supply the conclusion and then complete a knowledge test. Participants' beliefs about quick learning, referring to the question if learning occurs quickly or not at all (again compare Dweck, 1999), predicted both the quality of the conclusions they wrote as well as their performance in the knowledge test. The issues revealed that the more participants believed that learning occurs in an all-or-none manner, the more likely they were to write oversimplified conclusions. Additionally, such students were more likely to show poor performance in the knowledge test. Licht and Dweck (1984) provided evidence on the special importance of ability aspects in the case of ill-structured or confusing information. In their study, fifth graders were taught new material by means of instruction booklets. The booklets contained an irrelevant introduction which was either clear and straightforward or rather confusing. Participants' attributional style (helpless response or mastery-oriented response) was assessed. Results showed that when the instruction booklets did not contain confusing information, both helpless and mastery-oriented participants were equally likely to master the material and learned with equal facility. However, when participants processed confusing information, mastery-oriented participants outperformed helpless participants, suggesting that the confusing information was encountered with difficulty and it provoked ineffective functioning in the helpless participants. Helpless participants focused on their perceived lack of ability and perceived the task as threatening, while mastery-oriented participants saw the information provided as an opportunity for learning something new. Licht and Dweck (1984) concluded that performance should be considered as being "a function of how well a child's achievement orientations fit with the acquisition demands of the material" (p. 634). In sum, studies provide evidence for the conclusion that aspects of abilities, both stable ability beliefs and more task-specific beliefs, play a prominent role when people have to process scientific information. The specific role of beliefs about abilities in processing inconsistent information should be investigated in further detail. For example, for an in-depth view of the multiple facets of the construct, the role of such beliefs in processing inconsistent information could be compared to its role in processing consistent information. Furthermore, the interplay between beliefs about abilities on different layers (e.g., trait-like beliefs versus ability appraisal in a specific situation) is an under-researched topic.

6.5 On the Role of Epistemic Beliefs in Processing Scientific Information

During the last two decades, epistemic beliefs have become a target of increased research interest in developmental and educational psychology (Bendixen & Feucht, 2010; Hofer & Pintrich, 2002; Khine, 2008). Estes, Chandler, Horvarth, and Backus (2003) define epistemic beliefs as "our commonsense understanding of the origins and limits of human knowledge" (p. 626). Perhaps, the most prominent definition of the construct originates from Hofer and Pintrich (1997), who emphasized that epistemic beliefs involve "two core sets of concerns: the nature of knowledge and the nature or process of knowing" (p. 112). How one conceptualizes knowledge and how it changes over time are seen as aspects of the nature of knowledge, while considerations about where knowledge comes from and how to make justifications refer to beliefs about the nature of knowing. Despite their different underlying theoretical assumptions, studies on the development and change of epistemic beliefs indicate that epistemic beliefs range from a less advanced view to a more advanced view,[2] and develop through life experiences and educational experiences (Kuhn & Weinstock, 2002). Prototypically, individuals initially believe that knowledge is certain and stable, either true or false, and can be handed down by an authority. Over time, they become convinced that knowledge is more complex and relativistic, accept the uncertainty and changeability of truth, and shift to the notion that knowledge is construed individually.

People have to solve an ill-structured problem when they process complex information, such as a multitude of information (Spiro, Feltovich, & Coulson, 1996), and especially when they come across inconsistent information. Spiro and colleagues have outlined very early (e.g., Jacobson & Spiro, 1995) that epistemic beliefs are important when dealing with ill-structured problems. For example, epistemic beliefs determined how far people integrate new knowledge with prior knowledge. The studies presented in the following indicate that a critical reflection of scientific information found on the Internet requires a realistic view of the boundaries and origins of scientific knowledge and, therefore, appropriate beliefs about the nature, justification, and development of scientific evidence.

Research has shown the impact of epistemic beliefs on the understanding of single texts. For example, believing in certain knowledge predicts inappropriately absolute conclusions (Schommer, 1990). Mason and Boscolo (2004) investigated the influence of high school students' epistemic understanding on the critical interpretation of a dual-position text. After participants' epistemic understanding was assessed, participants were assigned to three groups of different epistemic positions, indicating whether participants primarily held a less advanced, moderate, or more advanced view on the nature of knowledge. All participants read a scientific text about genetically modified food, introducing both the position in favor and against the food. After reading the text, participants were asked to write a conclusion to the text. Findings revealed that both students with more advanced and with moderate epistemic understanding reflected better on the inconclusive nature of the debate on transgenic food (they, e.g., suggested that more scientific studies on the topic were needed) than students with less advanced beliefs.

The previous studies notwithstanding, information on the Internet differs considerably from single text documents. An almost unlimited number of different sources is available, which do not necessarily present a reliable account of a given topic (Stadtler & Bromme, 2008). Therefore, the role of epistemic beliefs should be even more important when processing multiple sources. In her influential theoretical approach on the rule of epistemic beliefs in online searching, Hofer (2004) elaborates that when people search the Internet for information, they must solve various questions. Evaluating the veracity of the information obtained and deciding what kind of evidence they accept for justifying specific claims is required. Furthermore,

[2] Due to the ongoing discussion on the unfortunate and overbearing connotations of the commonly used labels "naive" versus "sophisticated" for the differing complexity of epistemic beliefs (especially in educational psychology research), we use the terms "less advanced" and "more advanced" to point to the continuum on which epistemic beliefs are assumed to develop.

they must solve conflicts between various perspectives of knowledge and integrate conflicting evidence into a viable framework of personal understanding, as well as make decisions. Hofer (2004) explained that answers to such considerations will be influenced by epistemic beliefs, and that such epistemic assessments of information will affect decision making when searching for information about a problem.

Several empirical studies examine the relation between people's epistemic beliefs and their online searching strategies (Bråten, et al. 2005; Tsai & Chuang, 2005; Whitmire, 2004, Wu & Tsai, 2007). Whitmire (2004) found that participants' level of epistemic beliefs (referring to Baxter Magolda's (1992) epistemic reflection model) affects information-seeking behavior. For example, participants holding a less advanced view predominately selected information sources consistent with their views while avoiding conflicting information. Moreover, they were not able to determine the authority or usefulness of conflicting sources. In contrast, participants with more advanced beliefs knew several ways to evaluate Internet sources. Van Oostendorp and Juvina (2006) summarized that epistemic beliefs are of special interest when it comes to the question of whether recipients of multiple sources "want to connect seemingly isolated bits of information [or whether they] try to construct an integrated understanding of the presented information or not" (p. 5). This has been empirically underlined by studies of Bråten and Strømsø (e.g., 2006a, 2006b). They found that participants' (teacher students) epistemic beliefs can enhance or constrain the understanding of multiple, partly conflicting texts in a way that only students holding more advanced beliefs gained an adequate understanding from multiple sources and were better at conflating information from multiple perspectives, whereas students holding less advanced beliefs understood identical content to a greater extent when presented in a single-source, textbook-like format.

6.6 How to Empirically Assess the Role of Epistemic Beliefs and Beliefs About Abilities in Information-Rich Environments?

In the following section, we argue that the process of searching for scientific information on the Internet is an excellent test bed for investigating how and when people refer to ability explanations and epistemic explanations when encountering incoherent or conflicting knowledge claims. In our view, searching for scientific information on the Internet provides a prototypic situation for processing competing knowledge claims. Furthermore, we have outlined that finding the "right" explanation for the occurrence of contradictions between scientific information is an important (self-regulatory) competence. We have emphasized that beliefs about abilities and epistemic beliefs contribute to adequately processing contradictory scientific information. Given that research explicitly focusing on people's explanations of contradictions from multiple sources on the Internet is lacking, we have conducted several studies on beliefs about abilities and epistemic beliefs when processing information on the Internet.

In a first attempt to obtain a more comprehensive picture of the role of epistemic beliefs and beliefs about abilities when processing information on the Internet, we focused on participants' reactions to conflicting information about a medical topic on the Internet (cf. Kienhues & Bromme, 2010). Participants ($n = 25$) searched the Internet for 30 min for information on cholesterol to advise a fictitious friend about treatment. Fifteen web sites were preselected for the Internet search. All web sites presented information in a predominantly text-based manner. Web sites were devised to conflict with regard to four main aspects of the discussion on the causes and treatment of high cholesterol: (a) the hypothesis that food high in cholesterol influences the cholesterol level; (b) the hypothesis that high cholesterol can cause arteriosclerosis or heart attacks; (c) the idea that cutoff values can be defined for high cholesterol; and (d) the idea that medication, at least after trying alternative methods, is a very useful way to lower high cholesterol. While engaged in the Internet search, participants were interrupted every 2 min and prompted to retrospectively recall what they were thinking at the moment. Participants' utterances were coded with regard to the four common dimensions of epistemic beliefs (cf. Hofer & Pintrich, 1997: certainty of knowledge, simplicity of knowledge, source of knowledge, justification for knowing), but also with regard to beliefs about abilities, meta-cognitive regulation of the information search and cognitive information processing (cf. Kitchener, 1983). Coding led to a comprehensive description of the utterances to assess the processes when encountering conflicting information on the Internet. The first revealing result was that participants judged information on the Internet epistemically (cf. findings of Mason and Boldrin, 2008). Different aspects of epistemic beliefs are elicited when processing conflicting web information and are overtly verbalized. Note that participants were not explicitly asked to evaluate knowledge claims. The findings, therefore, indicate that epistemic beliefs play an active role in everyday thinking, which is consistent with Hofer (2004) that "students can do and make epistemic judgments" (p. 52). More specifically, in our study, the categories "justification for knowing" 76%; e.g. participants focused on the weakness of findings concerning the "causal" relationship between high cholesterol and cardiac infarction), "source of knowledge" 64%; e.g. participants questioned the credibility of a web site), and "simplicity of knowledge" 64%; e.g. participants searched for two-sided information) were well represented. In contrast, utterances with regard to the "certainty of knowledge" 12%; e.g. participants were open for a new interpretation of hypotheses) occurred only rarely. An important result pertaining to the beliefs about abilities was that 64% of the participants mentioned aspects referring to ability once or several times. For example, they claimed that they were overwhelmed by all the information accessed and that they did not have an idea how to deal with it or that they did not (yet) have a clue about the question at hand. Utterances referring to personal ability were more often negative (56%; e.g., "There is so much information, I have no idea how to sort it," "So far, I am just confused") than positive (32%, e.g., "I now already feel quite well informed"). Overall, ability utterances often took into account individuals' difficulties in understanding the information, for example, worries and concerns over solving the task, and they often referred to (self-regulatory) judgments of one's ability. In sum, this qualitative study provides first evidence for the assumption that processing conflicting information on the Internet elicits *both* aspects of personal epistemology *and* aspects of personal ability.

In a subsequent study, participants ($n=64$) also searched the Internet for cholesterol information to advise a fictitious friend about treatment (cf. Kienhues, 2010). We investigated how far a questioning of one's processing competence of specific information is an interpretative answer to the difficulties encountered when making sense of (conflicting) Internet information. Participants were randomly assigned to two different conditions: a conflict group provided with 15 preselected web sites with conflicting contents (the same web sites were used as those in the study described above) and a consistency group provided with 15 preselected web sites with consistent contents (web sites chosen for this group were consistent with regard to the four main aspects of the discussion on the causes and treatment of high cholesterol as described above). To investigate whether (negative) beliefs about abilities are especially elicited by the specific type of information, we measured participants' general self-concept of own competencies. We hypothesized that the global self-concept measure should only be a reliable predictor for participants' concrete beliefs about abilities elicited during Internet search when encountering consistent information. In the case of conflicting information, the predictive power of the self-concept variable should be lessened. In the concrete situation of being confronted with conflicting information, participants may attribute the problem of making sense of the conflicting information (at least partly) to their own limits of understanding the information and to processing it properly, even though they would not normally lack self-confidence. We applied a scale of a global self-concept measure (consisting of eight items and focusing on participants' self-concept of own competencies; FKK, Krampen, 1991) before the Internet search. Additionally, after the Internet search, we administered a Likert-scaled instrument retrospectively assessing participants' concrete reasoning about their abilities during Internet search. This one-dimensional instrument consisted of eight items and assessed to what extent participants had thoughts of insufficiency concerning their knowledge for dealing with the specific task and felt able to deal with problems during their Internet search. We conducted a hierarchical moderated regression analysis (Cohen, Cohen, West, & Aiken, 2003) to test the relation between the general self-concept of own competencies and reasoning about abilities. In detail, we wished to investigate whether specific reasoning about abilities is elicited by the specific kind of information processed. The dependent variable was reasoning about abilities. Predictor variables were general self-concept of own competencies (as measured with the FKK subscale), the type of information processed (conflicting information vs. consistent information), and the interaction of the FKK subscale and type of information processed. Results revealed that a model including the interaction term contributed to an increment of explained variance over the variance contributed by a model without the interaction term, and it accounted for 52% of the variance in reasoning about abilities. There was a main effect for the general self-concept of own competencies and also an effect for the kind of information processed. A moderating effect was identified by a significant beta weight for the interaction term.

Consistent with these results, an analysis of the single slopes for the regression of the continuous predictor variable general self-concept of own competencies on the outcome variable reasoning about abilities for both kinds of information processed revealed only a significant positive effect of general self-concept of own abilities in the consistency condition. The global, trait-like measure of self-concept of own competencies was only a reliable predictor for participants' concrete reasoning about their abilities in the case of consistent information. Participants who generally believed in their competencies also felt quite capable of solving the specific task when processing consistent information, which is the kind of relation one would expect. In contrast, in the case of conflicting information, the predictive power of the general variable was not significant. For example, although participants are generally self-confident, they nevertheless attributed the problem of making sense of the conflicting information (at least partly) to their own limits to understand the information and to process it properly. Therefore, in processing conflicting information, questioning one's ability is a reaction to the problems encountered and does not derive from the general competency self-concept. These results underscore the hypothesis that the type of information encountered has some influence on beliefs about abilities. Furthermore, they confirm that participants acknowledged the demands of the specific situation.

In a third study ($n = 100$) we investigated, among other aspects, the influence of processing either conflicting or consistent medical information on the Internet on participants' topic-specific epistemic beliefs (cf. Kienhues, Bromme, & Stadtler, 2010). Similar to the previous two studies, participants searched the Internet for cholesterol information to support a fictitious friend in deciding on a medical treatment (the web sites provided were the same as in the second study outlined). Participants were randomly assigned to the conflict group, the consistency group, and a control group (which is not important here). The eight-item scale administered to measure topic-specific beliefs after the Internet search assessed the clear-cut solvability of the task, for example, whether more than one answer could be correct, whether experts would clearly know, and whether everyone who searches the web on the topic would come to the same solution. Results showed that the two intervention groups differed in topic-specific beliefs after the Internet search. The group processing conflicting information reported less belief in the possibility of finding the one best solution for the task at hand, which was whether or not to take medication to lower high cholesterol. They stated that different opinions on the question at hand may all be (partly) right, whereas the group processing consistent information held a more positivistic view. Therefore, processing the different kinds of information evoked qualitatively different beliefs. The difference between the two intervention groups may indicate that contradictions were assigned to the epistemology of the topic.

In summary, considering both the role of epistemic beliefs and the role of beliefs about abilities appears to be beneficial when investigating information processing on the Internet. The extent that each type of belief influences processing can be assessed using a qualitative approach and quantitative approach. Future research should especially consider the different possible layers of beliefs about abilities (see above) in further detail.

6.7 Conclusion: Beliefs About Abilities and Epistemic Beliefs Indicate Cognitive Flexibility in Information-Rich Environments

From the three studies presented, we have gained an understanding that when processing scientific information on the Internet, both epistemic beliefs and beliefs about abilities play a role.

Results of the first study suggest that the kind of information encountered influences which epistemic categories participants consider. Hofer (2004) assumed on the basis of her study that certainty, as well as simplicity of knowledge, are rather tacitly held beliefs. In our study, the category simplicity of knowledge was frequently overtly expressed, probably because of the kind of information processed. Participants realized conflicts between knowledge claims and, therefore, found searching for pros and cons for such knowledge claims necessary. Such exemplar findings show that epistemic judgments of information on the Internet appear to be well adjusted to the demands of the information situation. The results also indicate that these judgments influence the information search process.

Results of the second study reveal participants' cognitive flexibility with regard to their ability judgments. Dependent on features of the situation, in this case whether the information processed was conflicting or not, participants either referred to a trait-like concept of own competencies in their concrete reasoning about their abilities or they did not. Results of the third study demonstrated that, again, participants were adaptive to the kind of information they encountered in forming their topic-specific beliefs while searching the web sites.

In conclusion, our studies showed that when processing information on the Internet, participants adjust their beliefs to the specific context in various ways. Moreover, we conclude that for an adaptive and flexible response to the different situational demands of information-rich environments, both beliefs about abilities and epistemic beliefs are important and should be considered. In our view, cognitive flexibility also manifests in the process of finding a suitable and adapted explanation for the experienced inconsistencies, and it provides the means to flexibly adjust different possible explanations for experiencing uncertainties in scientific knowledge.

Future research should especially focus on the interplay between epistemic beliefs and beliefs about abilities. For example, the case might be that people begin attributing occurring conflicts between information on the Internet to their own lack of knowledge to make sense of the information at hand, but during the Internet search, when they encounter more and more conflicting scientific information, they might conclude that the knowledge about the topic as such is not (yet) well established. People's decision about how to attribute conflicts between information is likely to be less black or white. In addition, we need further insight into conditions that might affect how people assign occurring inconsistencies in scientific information.

6.7.1 *Addendum: The Conceptualization of Epistemic Beliefs: Should Ability Aspects Be Included or Not?*

The argumentations in this chapter and the results we have obtained have implications for an enduring controversy within research on epistemic beliefs. The cognitive aspects we addressed in our studies separately, what we believe to be epistemic beliefs and beliefs about abilities, are quite often intertwined in studies on epistemic beliefs. While some researchers subsume beliefs about abilities to learn and to know under the concept of epistemic beliefs, others insist on a clear conceptual distinction between what they believe to be epistemic beliefs and beliefs about abilities. The boundaries of the construct epistemic beliefs have been discussed repeatedly, and recent debates have shown that researchers have not reached consensus about the definition of the construct (Elby, 2009; Sandoval, 2009).

On the one side, several authors have argued in favor for defining epistemic beliefs as views about the nature of knowledge, knowing, and learning to capture the complexity of the construct. In her groundbreaking work on the dimensionality of epistemic beliefs, Schommer (1990) introduced beliefs about learning into the theory of personal epistemology. She adapted the dimensions focusing on the speed and control of knowledge acquisition (innate ability and quick learning) from Schoenfeld's (1983) work on beliefs about mathematics and from the work of Dweck and Leggett (1988) on the beliefs about the ability to learn or the nature of intelligence. Schommer's (1990) paper-and-pencil self-report instrument (Epistemological Questionnaire, EQ) comprises five hypothesized dimensions of epistemic beliefs: beliefs in the source of knowledge (omniscient authority), the certainty of knowledge (certain knowledge), the structure of knowledge (simple knowledge), the speed of learning (quick learning), and the ability to acquire knowledge (innate ability). When factor-analyzing the questionnaire (although criticized because of the kind of factor analysis technique chosen, cf. Clarebout, Elen, Luyten, & Bamps, 2001), certain knowledge, simple knowledge, and the two factors on learning beliefs, innate ability and quick learning, were revealed. DeBacker, Crowson, Beesley, Thoma, and Hestevold (2008) summarized that in several studies for which the EQ was used, a three-factor solution represented the data best and that two of the three resulting factors (malleability of learning ability and speed of learning, respectively, speed of learning and ability to learn) addressed beliefs about learning rather than beliefs about knowledge and knowing. The Schommer questionnaire is probably the best-known instrument on the dimensionality of epistemic beliefs, and the conceptualization of epistemic beliefs inherent in the EQ is widely used. Various authors adopted Schommer's (1990) conceptualization of epistemic beliefs and included the same categories of beliefs in their attempts to improve questionnaires on the dimensionality of the construct. For example, Schraw et al. (2002) included the dimensions quick learning and fixed ability, and Wood and Kardash (2002) included items on the speed of knowledge acquisition and on characteristics of successful students.

In a recent discussion on the definition of epistemic beliefs, Elby (2009) advocated the conceptualization of epistemic beliefs originated by Schommer. He suggested that the community should avoid a hasty judgment on the definition of the construct, favoring that researchers await empirical and theoretical progress. In Elby's view, no good arguments exist for eliminating views about learning from what is perceived as personal epistemology or epistemic beliefs, as it is "neither necessary nor sufficient to avoid [this] conflation" (p. 147). One argument for retaining a broad definition is that students' views appear to not mind the boundaries between knowledge, knowing, and learning established by experts' definitions in a way that "some elements of students' personal epistemologies cut across the categories views about knowledge and knowing and views about learning" (p. 142).

On the other hand, various authors have claimed that some of the beliefs Schommer and others have proposed are not clearly epistemic. They argue in favor of a clear separation of learning beliefs from what they believe to be epistemic beliefs. This theoretical concern was advanced by Hofer and Pintrich (1997). They stated that Schommer's dimension fixed ability "[…] seems well outside the construct of epistemic beliefs, and it is not surprising that while it continues to appear as a factor it does not follow the patterns of other dimensions or appear to be a useful predictor in Schommer's research" (p. 108). In reference to what epistemology means in the context of philosophy, where epistemology is "concerned with the nature and justification of human knowledge" (Hofer & Pintrich, 1997, p. 88), Hofer and Pintrich (1997) argue that views of intelligence are not an integral part of epistemic beliefs, and they emphasize that beliefs about learning can be distinguished conceptually, even though they are probably related to beliefs about the nature of knowledge and how it is justified. In conclusion, they wish to conceptualize beliefs about the nature of knowledge and about the nature of intelligence or ability as separate constructs. Hofer (2001) summarized that epistemic beliefs refer to beliefs about knowledge and knowing and include beliefs about "the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs" (p. 355). She further suggested that the dimensions focusing on beliefs about ability are more meta-cognitive rather than epistemic in nature.

Sandoval (2005) also emphasizes the philosophical routes of research on scientific epistemology, and purports that scientific epistemology corresponds to "the nature of scientific knowledge, including the sources of such knowledge, its truth value, scientifically appropriate warrants, and so forth" (p. 635). In reference to Hofer and Pintrich (1997), he emphasized that research on epistemic beliefs has "suffered […] from a conflation of beliefs about knowledge with beliefs about learning" (p. 636). In a recent article, Sandoval (2009) underlined his plea for a narrow definition of epistemic beliefs in response to Elby's argumentation (2009, see above) that one should not (hastily) exclude learning beliefs from the definition of personal epistemology. He asked for a clear-cut definition because, otherwise, real theoretical progress might fail. He also argued that from an advanced personal epistemology, a distinction would be made between views about knowing and views about learning, which should therefore also be the case for a theoretical account on personal epistemology. He emphasizes that "a good theory of personal epistemology should help point the way toward instructional approaches that help people distinguish their views about knowing from their views about learning" (p. 151).

In this addendum, we have outlined the controversy about the inclusion of ability and learning conceptions into the construct of epistemic beliefs. We have emphasized throughout the chapter to take into account both beliefs about knowledge and knowing and beliefs about abilities when investigating how people deal with scientific information. Notwithstanding that much research remains to be done, we hope that our attempt will also contribute to a clarification of the contents and boundaries of the epistemic beliefs construct. Although such an empirical approach to the controversy is not likely to "solve" the conflict, it stresses that a clear-cut definition is necessary. Otherwise, empirical progress might fail when pursuing the research on the interplay between both types of beliefs. Blurring the conceptual distinction between both types of beliefs would hinder empirical research on their interaction.

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Chapter 7
Cognitive Flexibility and Epistemic Validation in Learning from Multiple Texts

Tobias Richter

7.1 Introduction

The concept of cognitive flexibility was introduced by Spiro and coworkers as an important objective for advanced learning in ill-structured domains (Spiro, Coulson, Feltovich, & Anderson, 1988). Advanced learners are those who already possess some knowledge about the content domain they are studying. Accordingly, advanced learning is more likely to be found in secondary education, in academic settings, or in professional training than in elementary education. A content domain is ill-structured if it meets two criteria: (1) a great deal of complexity, that is, a large number of concepts and relations between these concepts, and (2) irregular and inconsistent information. For advanced learning in such a domain, the instructional objective of cognitive flexibility may be defined as the ability to spontaneously restructure one's knowledge in response to changing cognitive demands posed by the learning material (Spiro & Jehng, 1990).

Cognitive flexibility is a relevant objective also for learning with multiple texts, a field that has started to attract research in educational psychology only a decade or so ago (Perfetti, Rouet, & Britt, 1999; Rouet, 2006; Rouet, Britt, Mason, & Perfetti 1996). In learning with multiple texts, learners study several texts (rather than just one textbook chapter) that represent divergent perspectives on the same issue. More often than not, learning with multiple texts is a case of advanced learning in an ill-structured domain. Imagine, for example, students having already acquired some basic knowledge in an area of science (e.g., climatology). Students might use the Internet to investigate more about a current topic, such as the causes of global warming. In the course of their studies, they might encounter a scientific article claiming that global warming is attributable to the fact that human activities have increased

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emissions of greenhouse gases. At some later point, they might read another text that discusses an increase in solar activity as a major cause of global warming. Still later, students might study another document that criticizes current climate models as being too unreliable to be used for predicting global warming at all. Thus, students are likely to be confronted with different theoretical viewpoints and inconsistent evidence. To learn successfully, they need to process various types of conflicting information, to assess the credibility and plausibility of this information, and to integrate it into a coherent and adequate point of view.

The scenario just described is typical for advanced learning in all areas of science. More often than not, advanced learning in science is based on multiple texts representing different positions in a scientific controversy, empirical studies with results that seem to contradict one another, or documents that present divergent interpretations of empirical findings and methods. In all of these cases, cognitive flexibility can be defined further as the ability to develop a justified point of view by adopting some arguments and rejecting others on rational grounds.

In the following sections, I argue and present some preliminary empirical evidence for three theoretical propositions. First, the goal of cognitive flexibility is suggested to require learners to actively validate incoming text information against previously acquired knowledge and beliefs (epistemic validation). Second, I sketch a model of the cognitive processes underlying epistemic validation. In particular, I will argue for the proposition that epistemic validation rests on two types of cognitive processes, that is, (automatic) epistemic monitoring and (strategic) epistemic elaboration. While epistemic monitoring is a regular part of comprehending the information presented in multiple documents, epistemic elaboration is optional and metacognitively more demanding. Importantly, learners can be expected to achieve cognitive flexibility only if they engage in epistemic elaboration. Among other things, learners' epistemological beliefs, that is, their beliefs about the nature of knowledge and knowing (Hofer & Pintrich, 1997) are a major determinant of whether or not they engage in epistemic elaboration. The third theoretical proposition claims that epistemological beliefs serve as a kind of declarative metacognitive knowledge that guides learners' strategic use of epistemic elaboration. In this way, epistemological beliefs can have an indirect but profound influence on cognitive flexibility in learning from multiple texts.

7.2 Cognitive Flexibility Requires Active Validation of Information

Learners studying multiple texts with conflicting arguments will be unable to achieve an adequate understanding of the content domain by merely processing the presented information in a receptive manner. Rather, they need to actively judge whether the information communicated by the various texts is true or plausible. In other words, learners need to evaluate the knowledge claims raised by the various documents with respect to validity criteria, such as (propositional) truth, logical consistency, or argument quality. These types of judgments may be termed *epistemic* *validation* (Richter, 2003). When forming these judgments, learners use their background knowledge and what they have already learned from previously studied texts as epistemic background for validating incoming text information.

Epistemic validation processes are largely ignored by the dominating theoretical approaches to text comprehension and learning from text. To be sure, all major theories in these fields acknowledge the relevance of prior knowledge for improving the quality of learning processes and outcomes. However, they restrict the functions of prior knowledge to setting constraints on the interpretation of text information (e.g., the construction–integration model, Kintsch, 1988, 1998), to an interpretative framework or scaffold for integrating new text information (e.g., schema theory, Anderson, 1985), or to a knowledge base for inferences and other cognitive activities by which learners enrich the information given (e.g., constructivism/constructionism, Bruner, 1973; Graesser, Singer, & Trabasso 1994). Their huge theoretical differences notwithstanding, all of these theories presuppose a supplemental relationship of text information and prior knowledge. The construction–integration model is a case in point. Because of its text-driven, bottom-up character, the model can handle conflicting information only by assigning negative links in the construction phase. In the integration phase, conflicts between propositions in the network are resolved mainly by strengthening some nodes and suppressing others. In this way, a stable situation model can be constructed even in the face of conflicting information. However, this is processed simply by capitalizing on some information while ignoring other information. Thus, from a text-driven model, such as the construction–integration model, one might be able to describe how one-sided, impoverished representations originate when learners encounter conflicting information (Otero & Kintsch, 1992). However, the model does not provide an explanation of how learners make sense of multiple documents with conflicting information.

Accumulating facts and enriching or scaffolding them with prior knowledge are successful strategies only for learning materials that are fully plausible and consistent. In contrast, if multiple texts present conflicting information or information that is inconsistent with prior knowledge, such a strategy is doomed to fail. In that case, learners can only arrive at a coherent representation of the content of these texts by actively using prior knowledge and previously acquired information to evaluate the plausibility of what a particular text tries to make them believe. This activity involves comparing competing claims raised by different texts and checking the quality of arguments to come up with an informed and justified point of view (Perfetti, Britt, & Georgi, 1995). In short, successful learning with multiple texts requires cognitive flexibility. Cognitive flexibility, in turn, requires epistemic validation.

7.3 Epistemic Validation Rests on Epistemic Monitoring and Epistemic Elaboration Processes

How can the cognitive processes underlying epistemic validation in learning with multiple texts be described? I suggest that epistemic validation rests on two types of processes that may be termed epistemic monitoring and epistemic elaboration.

The distinction between epistemic monitoring and epistemic elaboration maps onto the long-standing distinction of routine and efficient memory-based vs. slow and resource-demanding explanation-based processes in text-comprehension research (Graesser et al., 1994; McKoon & Ratcliff, 1992). In this section, the nature of epistemic monitoring and epistemic elaboration is outlined, and empirical evidence that supports the assumption of these processes is reviewed. An explanation is then provided on how cognitive flexibility in learning with multiple texts depends on the interplay of epistemic monitoring and epistemic elaboration.

7.3.1 Epistemic Monitoring: Routine and Efficient Detection of Inconsistencies

Epistemic monitoring processes routinely check for the consistency of prior knowledge and incoming text information. Provided that learners possess relevant prior knowledge that is active in working memory or can easily be made available by passive memory-based processes, epistemic monitoring processes are carried out routinely and efficiently. That is, they pose little demands on cognitive resources and are not dependent on processing goals (Richter, Schroeder, & Wöhrmann, 2009). In most cases, learners use their current situation model, that is, the referential representation of the content domain they have built up already during learning for monitoring the plausibility of new information (Johnson-Laird, 1983; Zwaan & Radvansky, 1998). In the scenario introduced above, students of climatology, who just read a document arguing that global warming is caused by human activities, are likely to have integrated some of these arguments into their situation model of global warming. When the students study another text arguing for solar activity as the main cause of global warming, the previously acquired arguments are activated from long-term memory (cued by concepts common to both texts such as causes of global warming), and the inconsistency is detected by epistemic monitoring. Due to the memory-based and routine character of epistemic monitoring, all of this occurs fast, with little cognitive effort, and regardless of the students' reading goal.

Evidence for routine and efficient epistemic monitoring processes comes from a large body of psycholinguistic research showing that inconsistencies between incoming information and currently active or easily accessible knowledge are detected quite regularly. Recent research from our work group provides direct evidence for the existence of these processes (Richter et al., 2009). In one experiment, words were presented rapidly (300 or 600 ms) one after another on a computer screen. At some words, the presentation stopped and participants were asked to judge whether or not the word was spelled correctly. Sequences of words formed simple assertions that were either true (e.g., fire trucks are red) or false (e.g., soft soap is edible). For trials in which the target word was the last word of an assertion, response latencies and error rates of the orthographical judgments were increased when the task required an affirmative response (i.e., the last word was spelled correctly)

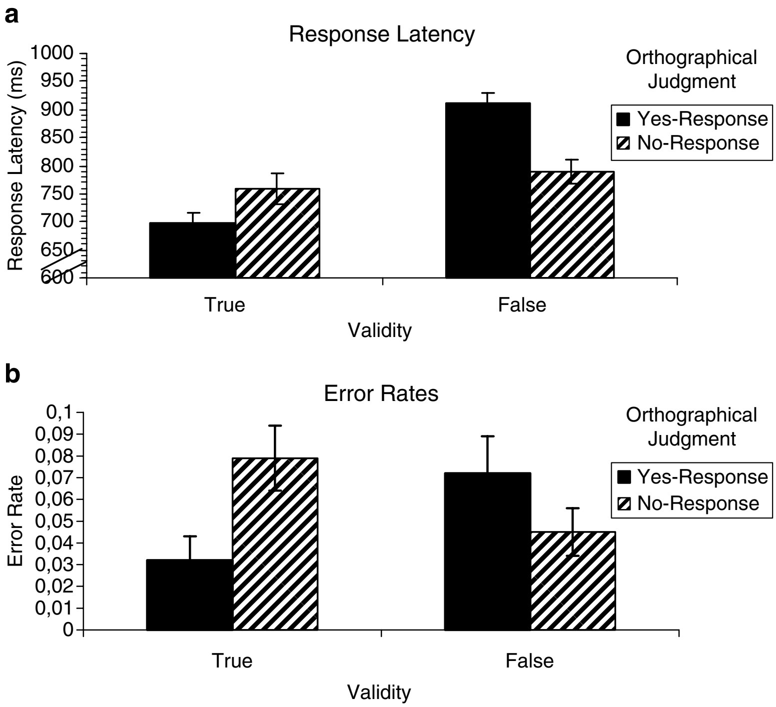

Fig. 7.1 Epistemic Stroop effect: Orthographical judgments concerning the last word of simple assertions take more time (**a**) and are more error prone (**b**) if the required response (yes vs. no) and the validity of assertions (true vs. false) are incongruent. For example, judging whether the last word of the false assertion *Computers have emotions* is spelled correctly takes longer and is more error prone compared to judging the last word of the true assertion *Cognac contains alcohol*. This pattern is reversed if the last word is spelled incorrectly (e.g., *emohtions* and *alcoholl*), requiring a no response for the orthographical judgment (Adapted from Richter et al., 2009, Figure 4. With kind permission from the American Psychological Association)

but the assertion was false. Response latencies and error rates were also increased when the task required a negative response (i.e., the last word was spelled incorrectly) but the assertion was true (Fig. 7.1). Thus, there was a Stroop-like effect suggesting that individuals routinely and unintentionally monitor the validity of information. This effect may be called epistemic Stroop effect.

In addition, experiments by Singer, Halldorson, Lear, and Andrusiak (1992) provide indirect evidence for the assumption that comprehenders routinely monitor the plausibility of implicit background assumptions (enthymemes) of causally related sentences. Inconsistent causal sequences such as Dorothy poured the bucket of water on the bonfire – The fire grew hotter, facilitated responses to questions such as Does water extinguish fire?, compared to temporal sequences that were used as controls. Similarly, there is evidence from reading-time and event-related potential studies that comprehenders monitor the logical consistency (Lea, 1995; Lea, Mulligan, & Walton, 2005) and situational plausibility of texts (Ferretti, Singer, & Patterson 2008; Singer, 2006) even if they do not follow an intentional validation strategy. In most cases, comprehension of sentences with inconsistent and implausible information was slowed down.

All of the studies mentioned in the last paragraph establish one important precondition for epistemic monitoring in text comprehension: Prior knowledge or previously encountered information relevant for detecting the inconsistency must either be currently active in working memory or it must be reinstated routinely and with little cognitive effort by textual cues. The passive memory-based processes involved here can be modeled computationally with the resonance-like activation mechanism implemented in the landscape model (Tzeng, van den Broek, Kendeou, & Lee 2005; van den Broek, Risden, Fletcher, & Thurlow, 1996). In this context, resonance means that concepts activated during reading by incoming text information will activate other concepts associated with it by means of spread of activation (McKoon, Gerrig, & Greene 1996; O'Brien & Myers, 1999). These concepts can be part of the mental representation of the text content as well as part of prior knowledge stored in long-term memory.

7.3.2 Epistemic Elaboration: Resolving Inconsistencies by Strategic and Knowledge-Based Processing

As a result of detecting an inconsistency between previously held beliefs and text information by epistemic monitoring, learners sometimes may initiate epistemic elaboration processes. In contrast to epistemic monitoring, epistemic elaboration is based on processes that are assumed to be slow, resource demanding, and under the strategic control of the learner (Richter, 2003). For these reasons, learners are likely to engage in these processes only if they are motivated and able to do so. Learners motivated to engage in epistemic elaboration study to come up with a justified point of view of how things really are (epistemic learning goal) rather than to accumulate information in an uncritical manner (receptive learning goal). The goal to memorize as much information as possible for later reproduction of this information, for instance, is probably widespread among students preparing for an exam, but it may effectively prevent learners from engaging in epistemic elaboration. Learners able to engage in epistemic elaboration should have sufficient cognitive resources (working memory capacity) available and possess relevant prior knowledge. If both the motivational and cognitive conditions are met, learners can use their prior knowledge to elaborate hypothetical truth conditions of an assertion or argument initially found implausible. In other words, epistemic elaboration processes evaluate the circumstances that – were they given – would render the questionable piece of information or argument valid (Johnson-Laird, 1983, p. 249). Ultimately, epistemic elaboration processes may lead to a conscious decision about whether a particular piece of information or argument is accepted as being valid or rejected as being invalid (for a detailed model-based account of these processes, see Johnson-Laird, Girotto, & Legrenzi, 2004).

Epistemic elaboration processes are accompanied by other knowledge-based comprehension processes such as elaborative and bridging inferences that learners use to establish hypothetical truth conditions or to search for evidence that could support some doubtful piece of information. As a consequence, epistemic elaboration can strongly foster learning by supporting learners in the construction of a rich situation model and the augmentation of an informed point of view on the content domain (Richter, 2003). For example, students of climatology in the sample scenario might start wondering how the inconsistency can be resolved that they noticed between the claim of one text that human activities are the main cause of global warming and the claim of the other text that solar activity is the main cause. They might actively search for further information in the texts and their own long-term memory, which would support or weaken either position. In the end, they would come up with an informed decision on which position is more plausible, and as a by-product, also with a rich situation model of global warming and its causes. However, the following criteria are important to keep in mind – that all of this can occur only if students follow the goal to gain an accurate and justified view on the causes of global warming, if their cognitive resources are not absorbed by other activities, and if they possess sufficient and relevant prior knowledge that they can use for epistemic elaboration.

Relative to epistemic monitoring, evidence for epistemic elaboration processes is still rather sparse. In experiments by Wiley and Voss (1999) on learning with multiple texts in history, students wrote more coherent essays with stronger causal links and scored better on inference and analogy tasks when they had received the instruction to write an argumentative essay, compared to the tasks to write a summary or a narrative text (for similar results, see Voss & Wiley, 1997). Given that the task to write an argumentative essay is likely to induce an epistemic learning goal, these results are consistent with the idea that strategic (i.e., deliberate) epistemic elaboration fosters situation model construction and the development of a justified point of view.

The view advocated here also incorporates the assumption that epistemic elaboration processes are initiated when an inconsistency between text information and prior knowledge is detected. This assumption implies that learners should benefit from texts with implausible information if they are motivated and able to engage in epistemic elaboration. The effect predicted by this somewhat counterintuitive assumption may be termed reverse validity effect because it resembles the well-documented reverse coherence effect (i.e., high-knowledge learners often benefit from incoherent texts, McNamara, Kintsch, Songer, & Kintsch, 1996). Richter (2003, Experiment 1) tested one part of this hypothesis in an experiment with university students who read expository texts that contained only valid arguments or a number of invalid arguments (argumentation errors). Participants read these texts either with an epistemic learning goal ("develop your own point of view!") or a receptive learning goal ("memorize facts!") in mind (time on-task was held constant). Participants reading the texts with the epistemic learning goal in mind showed better comprehension on the situation model level for texts with invalid arguments compared to the text with only valid arguments. Situation model strength was

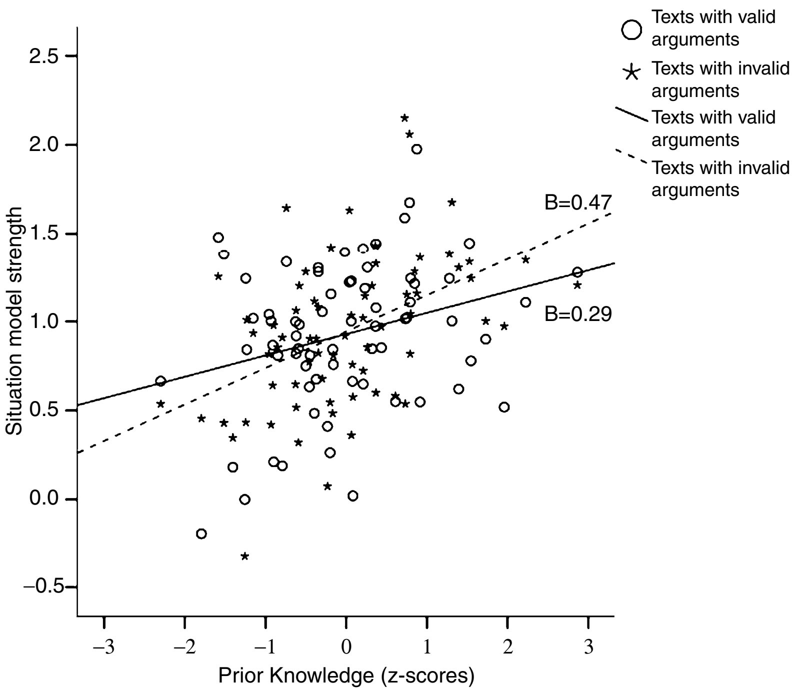

Fig. 7.2 Reverse validity effect: Invalid arguments lead to better comprehension on the level of the situation model when learners possessed sufficient prior knowledge to engage in epistemic elaboration. The figures display simple slopes for prior knowledge (with standardized regression coefficients) for texts with valid and invalid arguments. Situation model strength was measured with a variant of the recognition method proposed by Schmalhofer and Glavanov (1986) (Richter, Schroeder, & Wöhrmann, unpublished data)

assessed by means of responses to multiple-choice inference questions. Participants reading the texts with the epistemic learning goal also produced more arguments to support their stance toward the position of the text. For participants with the receptive learning goal, the pattern of results was reversed. Apparently, inconsistencies of text information and world knowledge evoked by texts with invalid arguments stimulated epistemic elaboration processes when participants were motivated to invest the cognitive effort needed for epistemic elaboration. A recent experiment from our work group focused on the second part of the reverse validity effect, that is, prior knowledge as a prerequisite for epistemic elaboration (Richter, Schroeder, & Wöhrmann, unpublished data). In this experiment, university students again learned with texts that presented either only valid arguments or valid arguments mixed with invalid ones. In support of the reverse validity effect hypothesis, participants possessing a large amount of prior knowledge were able to construct a richer situation model for the texts with invalid arguments compared to the texts with only valid arguments (Fig. 7.2).

7.3.3 Epistemic Monitoring, Epistemic Elaboration, and Cognitive Flexibility

The simple process model outlined in the preceding sections is also applicable to learning with multiple texts that contain conflicting information. The assumptions of two types of cognitive processes, one routine and efficient and the other strategic and resource demanding, yield precise predictions as to when learners achieve cognitive flexibility in learning with multiple texts and when they fail to do so. In particular, based on the process model, an assimilative and an elaborative mode of dealing with conflicting information during learning can be distinguished. These will be discussed in turn.

7.3.3.1 Assimilative Epistemic Processing

First, consider the outcome when a learner studying multiple texts lacks the motivation and/or the ability to engage in epistemic elaboration, for example, because the learner follows a learning goal that does not necessitate epistemic elaboration or lacks the cognitive resources or relevant background knowledge. In this case, only epistemic monitoring processes are carried out because these processes neither require a specific learning goal nor do they demand a large amount of cognitive resources. As a consequence, incoming information that conflicts with information from previously read texts is likely to be processed in an *assimilative mode*. Learners use their current situation model as the primary basis for epistemic monitoring. The current situation model, in turn, rests in large parts on the contents of previously read texts. Incoming information that is revealed by epistemic monitoring to be inconsistent with the current situation model is simply rejected and will not be integrated into the situation model. As a result, the situation model will be biased toward the contents of the texts read earlier. In sum, the process model of epistemic validation implies that learners often will not exhibit cognitive flexibility in dealing with conflicting information in multiple texts. Rather, they tend to stick to information they have already learned.

Several branches of research on learning, text comprehension, and social information processing suggest that the cognitively inflexible mode of assimilative processing seems to be the default way to deal with conflicting information. For example, numerous studies on conceptual change have shown that it can be quite difficult to change previously acquired knowledge and beliefs (Chinn & Brewer, 1993; Limón & Mason, 2002; Vosniadou, 1994). The notion seems plausible that these difficulties can partly be explained by assuming that students often rely on epistemic monitoring without engaging in epistemic elaboration. Research on the persistence of discredited or corrected information (continued influence of misinformation effect, Johnson & Seifert, 1994; Ross, Lepper, & Hubbard, 1975) suggests a similar conclusion. Johnson and Seifert (1994) used fictional news reports as text materials that were continuously updated during the experiment. In the course of updating, some of the information given in earlier reports was corrected by information provided later. Despite being explicitly corrected, the initial information continued to be used by participants in judgment and inference tasks. Interestingly, the research on the continued-influence-of-misinformation effect also sheds light on the conditions under which such effects occur. For example, Johnson and Seifert (1994) found that only pieces of (mis)information central to the causal chain of the reported events were likely to persist, whereas representations of less important details were easily altered. In a similar vein, self-generated causal explanations and knowledge-based inferences seem to amplify the continued-influence-of-misinformation effect (Anderson, Lepper, & Ross, 1980; Ross, Lepper, Strack, & Steinmetz 1977). Finally, recent evidence shows that the effects occur only when the initial information is consistent with participants' prior knowledge and beliefs (Lewandowsky, Stritzke, Oberauer, & Morales, 2005). Being part of the causal chain of a story and being elaborated by self-generated explanations or knowledge-based inferences, the initial information is more likely to be integrated into a situation model representation. Once the information is part of the situation model, it is immediately available for the epistemic monitoring of incoming information and can be used to detect and reject inconsistent information. Schroeder, Richter, and Hoever (2008) directly tested the hypothesis that epistemic validation and integration of information into a situation model representation are closely related to each other. In their experiment, university students read expository texts that contained implausible sentences. A multinomial models analysis of recognition and plausibility judgments revealed a close bidirectional relationship of validation and situation model construction. Plausible information was more likely to be integrated into participants' situation model than implausible information. On the other hand, information that was part of the situation model was more likely to be judged as plausible. Thus, once information has passed the epistemic gatekeeper and becomes part of a learner's situation model, it is used for monitoring the validity of incoming information. One consequence of this bidirectional relationship is that learners can hardly achieve cognitive flexibility in learning with multiple texts if epistemic validation does not go beyond epistemic monitoring.

7.3.3.2 Elaborative Epistemic Processing

Next, consider the outcome when a learner is both motivated and able to engage in epistemic elaboration of inconsistencies between multiple texts. In that case, the learner will actively search for arguments and evidence on both sides of the conflicting issue and elaborate hypothetical truth conditions. This mode of processing conflicting information may be termed *elaborative epistemic processing*. Overall, learning with multiple texts benefits from elaborative epistemic processing in several ways. First, by considering both sides of an issue, learners are likely to make well-justified and rational decisions on what view they should adopt. Second, they will know arguments and evidence for and critical arguments against both sides of the issue, which will make it easier to change their mind should they encounter new information. Third, they will also pay more attention to the sources they are studying and encode meta-information about the sources, which is relevant for assessing their credibility (e.g., characteristics of the author, text genre, and form of publication) along with the factual information (sourcing, Britt & Angliskas, 2002). All of these aspects are central to cognitive flexibility in learning with multiple texts.

7.3.4 Epistemological Beliefs Serve as Declarative Metacognition Guiding Epistemic Elaboration

The assumption that epistemic elaboration processes are under the strategic control of learners is germane to epistemological beliefs. Epistemological beliefs are subjective theories about characteristics, criteria, and justification conditions of knowledge (Schmid & Lutz, 2007). These theories, which can be more or less coherent, complete, and adequate, are the subjective counterpart of objective theories developed in classical epistemology and the philosophy of science, in a similar way as declarative metacognitive knowledge consists of subjective theories about the subject matter of cognitive psychology (e.g., Flavell & Wellman, 1977). In this sense, epistemological beliefs may be regarded as an epistemological (as opposed to cognitive-psychological) type of metacognitive knowledge (Hofer, 2004; Kitchener, 1983; Mason & Boldrin, 2008). As such, epistemological beliefs are relatively stable learner characteristics that can have a profound influence on the cognitive flexibility that learners can achieve in learning with multiple texts. According to the framework outlined here, epistemological beliefs exert this influence via epistemic elaboration processes.

Generally speaking, a well-developed epistemological position (such as commitment within relativism, Perry, 1970, or reflective judgment, King & Kitchener, 1994) makes it more likely that learners follow an epistemic learning goal which, in turn, is a precondition for epistemic elaboration. A key dimension in most structural models of epistemological beliefs is the perceived certainty of knowledge (Hofer & Pintrich, 1997). Learners who believe that knowledge is certain and never changing are likely to regard expository texts and scientific publications as a source of unquestionable information. Thus, the fundamental insight that knowledge is fallible and changing as a matter of principle is a precondition to engage in epistemic elaboration. In support of this general hypothesis, a study by Richter and Schmid (2010, Study 2) found the belief that knowledge is uncertain and changing to enhance the likelihood that university students engaged in epistemic strategies such as actively checking whether knowledge claims are backed up by sound reasons. This effect was mediated by epistemic curiosity and moderated by learners' extrinsic motivation (Fig. 7.3). Epistemic curiosity was measured by items referring to affective or motivational reactions to cognitive conflicts (e.g., *I want to know which theory is correct in the explanation of a certain phenomenon*). Thus, the belief that knowledge is uncertain or changing seems to predispose learners to be curious to learn

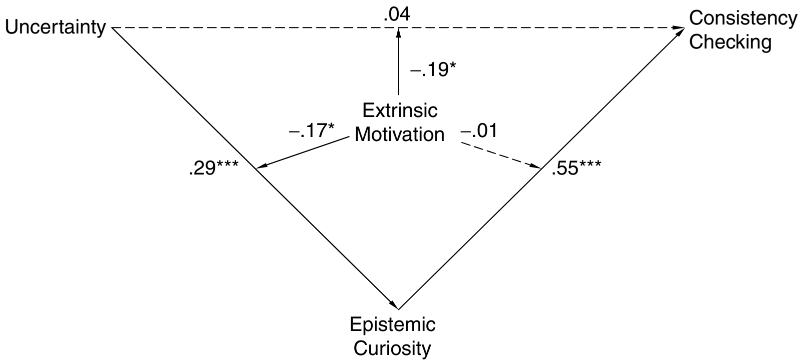

Fig. 7.3 The epistemological belief that knowledge is uncertain and changing fosters the use of epistemic strategies by evoking epistemic curiosity, but this mediator relationship holds only if extrinsic motivation is low (moderated mediation). *Arrows pointing* at other arrows indicate moderator effects (moderated mediation, standardized coefficients) (Adapted from Richter & Schmid, 2010, Figure 3. With kind permission from Springer Science+Business Media)

how things really are. This motivational state, in turn, can enhance the likelihood and the intensity of epistemic elaboration. On the other hand, this relationship can easily be undermined by extrinsic motivation. If, for example, learners focus on achievement goals (e.g., to score well in an exam), effects of epistemological beliefs on epistemic curiosity and epistemic elaboration seem to be suspended.

However, the belief that knowledge is uncertain and changing, per se, might not be sufficient to induce an epistemic learning goal. For example, a relativist position which also incorporates this belief would not be compatible with such a goal. For this reason, the framework outlined here implies that a relativist position ("Some people say A, other say B – that is ok for me") will usually cause superficial understanding because it essentially prevents learners from epistemic validation. This process occurs because learners strive to make a rational decision on the acceptance or rejection of claims and arguments only when they believe that knowledge is uncertain and fallible, and, at the same time, that there are objective standards of knowledge and the justification of knowledge claims. In other words, the dimension of certainty is likely to interact with the perceived objectivity or need of justification when it comes to epistemic elaboration. Recent data from our work group on the reverse validity effect suggest that this is indeed the case (Richter, Schroeder, & Wöhrmann, unpublished data). We found that only learners who believe that knowledge is subject to change but is nevertheless structured and objective (measured with the dimensions Variability and Texture of the instrument CAEB, Stahl & Bromme, 2007) were able to benefit from a text that contained invalid arguments. In contrast, holding only the belief that knowledge is subject to change or only the belief that knowledge is structured and objective was not sufficient to produce a reverse validity effect.

In sum, emerging evidence supports that epistemological beliefs serve as a special type of metacognitive knowledge that determines whether and to what extent learners engage in epistemic elaboration or epistemic strategies. According to the framework outlined here, this implies that epistemological beliefs should also have a profound impact on cognitive flexibility in learning with multiple texts, and that this impact should be mediated by epistemic elaboration. Recent research by Pieschl, Stahl, and Bromme (2008) on the role of epistemological beliefs in hypertext learning suggests that there might be some truth to this supposition. In their study, university students with more sophisticated epistemological beliefs accessed more complex and deeper-level nodes in a hypertext learning environment on genetic fingerprinting. According to Pieschl et al. (2008), this finding shows that epistemological beliefs serve as standards for calibrating learning processes. This interpretation is consistent with the model advocated here. However, direct tests of the relationships between epistemological beliefs, epistemic elaboration, and learning with multiple texts are still lacking.

7.4 Conclusion

This chapter described a cognitive process model of epistemic validation in the comprehension of multiple texts with conflicting information. The model is based on the distinction of routine, memory-based epistemic monitoring and strategic, resource-dependent epistemic elaboration processes. Several empirical findings such as the epistemic Stroop effect (Richter et al., 2009), plausibility effects on situation model construction (Schroeder et al., 2008), or the reverse validity effect corroborate the assumption that these two types of processes underlie epistemic validation.

What is familiar and what is new about the process model of epistemic validation? Generally speaking, the present model proposed is compatible with current theories of text comprehension and learning from text, but it also goes beyond these theories in important respects. By assuming that comprehenders monitor the consistency of incoming information, the model incorporates a specific type of top-down processes as a regular part of comprehension. On that score, the model outlined here differs from theories such as the construction–integration model (Kintsch, 1988, 1998), which concentrate on text-driven processes only. By combining memory-based processes (epistemic monitoring) and explanation-based processes (epistemic elaboration), the process model picks up the general and increasingly popular idea that both types of processes contribute to text comprehension (van den Broek, 2005).

Finally, apropos of the comprehension of multiple texts, the process model of epistemic validation fits well with the theoretical framework proposed by Rouet et al. (1996) and Perfetti et al. (1999), which may be regarded as the starting point of a systematic study of multiple text comprehension. However, the notion that an adequate comprehension of multiple texts that includes cognitive flexibility requires the active validation of conflicting information adds a novel aspect to the picture. It implies a number of interesting and empirically testable predictions. To date, few of these predictions have been tested. Hence, there is much empirical work ahead. The endeavor appears to be worthwhile.

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Chapter 8
Development of Cognitive Flexibility and Epistemological Understanding in Argumentation

Beate Sodian and Petra Barchfeld

8.1 Cognitive Flexibility and Perspective Taking

Cognitive flexibility is often defined as multiperspectivism (Spiro, Coulson, Feltovich, & Anderson, 1988), that is, the ability to form multiple representations of a given situation or task. This type of processing facilitates flexibility in responses to varying situational demands, for example, to switch mental sets in response to changing relevant cues in the environment, and complementarily to maintain a mental set when changes are irrelevant (cf., Sternberg & Powell, 1983). In short, cognitive flexibility enables people to think of alternatives, alternative interpretations of an instruction, a piece of text, a painting, alternative explanations for an event or a natural phenomenon, alternative viewpoints associated with perceptual or epistemic perspectives, and alternative behavioral options, such as strategy choices or decisions.

Perspective taking is a classic research area of cognitive development. While Piaget claimed that children below the age of 6 or 7 years were fundamentally egocentric, in the sense that they lacked a basic understanding of *perspectives*, recent research has demonstrated forms of perspective differentiation (distinguishing between what I see and what another person sees) in children as young as 2.5 years (Lempers, Flavell, & Flavell, 1977). Looking-time studies indicate that infants as young as 9 months non-egocentrically represent what another person can see (cf., Baillargeon, Scott, & He, 2010; Sodian, 2011, for reviews). Only recently, however, has the development of social perspective taking been theoretically and empirically linked to the development of cognitive flexibility.

A basic aspect of linguistic flexibility is to provide alternative names for the same target, such as "rabbit" and "bunny" or to label an object either in terms

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of the superordinate category ("animal") or the basic-level category ("dog"). In natural language acquisition, young children appear to assume for some time that each category can only have one name (mutual exclusivity constraint; Markman, 1989). But even after they have acquired two labels for an object (e.g., they identify the correct referent both when asked for "the bunny" and for "the rabbit"), children find it extremely difficult to provide an alternative label for an object in experimental tasks, or to judge the correctness of a puppet's production of alternative names. Such "naming games" are only mastered around the age of 4 years (Doherty, 2000; Doherty & Perner, 1998; Perner, Stummer, Sprung, & Doherty, 2002).

Another important aspect of cognitive flexibility is to switch between alternative dimensions when categorizing objects, for example, between color and shape. Extradimensional shifting abilities in children have been assessed with the Dimensional Change Card Sorting (DCCS) task (Zelazo, Müller, Frye, & Marcovitch, 2003). In the DCCS task, children are typically first asked to sort according to one dimension (e.g., color), and then according to another dimension (e.g., shape). Three-year-olds have no problems in the preswitch phase when sorting the cards according to one dimension, but they have difficulty in the postswitch phase when required to sort according to the contrasting dimension. The extradimensional shift is typically mastered around the age of 4 years. Extradimensional shifts are more difficult for 3-year-olds than reversal shifts within one dimension (e.g., first all apples go with the apple, then, in the "silly" game, all apples go with the banana). These findings suggest that 3-year-olds' difficulty arises from the problem of representing one and the same object simultaneously in two different ways (e.g., as a red one, as a round one) (Kloo, Perner, Kerschhuber, Dabernig, & Aichhorn, 2008).

Interestingly, performance on alternative naming tasks and on the DCCS is strongly associated with the mastery of false belief tasks around the age of 4 years, even when chronological age is controlled for. The correlation is not simply due to common inhibitory demands of the tasks (Kloo & Perner, 2003; Perner, Lang, & Kloo, 2002; Perner, Stummer, et al. 2002). The false belief task is a social perspective-taking task in which children typically have to predict a story figure's (Maxi's) mistaken action based on Maxi's false belief, that is, they have to represent the story figure's wrong representation of a state of affairs independently of their own knowledge of the true state of affairs. Perner, Stummer, et al. 2002 argue that a common conceptual understanding of *perspective* underlies the mastery of these apparently quite different tasks. Both the DCCS and the alternative naming tasks require an understanding that one entity can be described or viewed in different ways. By applying alternative sortals (the round object, the red object, the cat, and the animal), the entity referred to is individuated in different ways. This application of alternative sortals is a case of truth-compatible perspectives, whereas the false belief task requires the representation of truth-incompatible perspectives. Perner, Stummer, et al. (2002) further distinguish between switching perspectives (i.e., taking different perspectives at different times), and confronting perspectives (representing two perspectives simultaneously; understanding that there are different perspectives). They argue that the ability to *confront* perspectives emerges around the age of 4 years and underlies success at both social and nonsocial perspective-taking tasks. In this analysis, an explanation is provided for understanding perspectives, and how cognitive flexibility, in the sense of "thinking of alternatives," requires an understanding of perspectives. In this chapter, we apply this analysis to more complex forms of "thinking of alternatives" that emerge later in development. In particular, we will investigate whether the ability to confront different representations of one entity is developmentally related to the ability to distinguish between true and false representations at more advanced levels of perspective taking, concerning the representation and evaluation of alternative theories.

8.2 Thinking of Alternative Causal Theories: A Case of Advanced Perspective Taking

Even young children strive to causally explain phenomena. According to some views of cognitive development (Carey, 1985; Gopnik & Meltzoff, 1997), they hold domain-specific intuitive theories, for example, an intuitive biology or an intuitive cosmology. Since these theories are intuitive, they are usually not accessible to conscious reflection. Thus, children who maintain a geocentric view of the sun circling around the (flat) earth will usually not explicitly think about alternatives to this theory. Thinking about alternatives to one's own theory can be seen as a case of advanced perspective taking. Simple perspective taking requires reflection on simple beliefs that can be determined to be right or wrong in a straightforward way (e.g., "the chocolate is in the red cupboard"). In contrast, theories are characterized as coherent sets of interrelated beliefs within an explanatory framework. Thus, reflecting on alternative theories requires the representation of systems of beliefs rather than simple beliefs. While simple beliefs can easily be determined as true or false, the evaluation of a theory is a complex, multi-step process, involving reasoning from sources of evidence that are often indirect.

Research on the development of scientific reasoning, and on skills of argument, suggests that even adults have difficulty making their own causal theories about everyday phenomena, such as theories about causes of the crisis of the banking system, or the causes of earthquakes an object of conscious reflection (Kuhn & Franklin, 2006). Kuhn (1991) concluded from an in-depth investigation of informal reasoning in adolescents and adults that laypersons often fail to differentiate between theories and evidence, and conceive of causal theories as "script-like representations of the way things are." This can be seen as a lack of cognitive flexibility in the sense that people fail to conceive of alternatives to their own theory, or in the sense that they fail to decouple their theories (ideas) from evidence (data).

In Kuhn's (1991) study, participants were requested to develop a causal theory concerning a common social problem, such as why some children fail at school or why some prisoners return to crime after being released from prison. The participants were then requested to generate evidence to support the subjective theory.

After that, they were asked for an alternative theory for criminal recidivism, for evidence supporting that alternative, and for evidence against the alternative, thus, supporting their own theory.

Only a minority of the adult subjects in Kuhn's studies (from 9% to 22%) consistently showed the ability to systematically evaluate their own subjective theories, to consider alternatives to their own theory, and to generate, contemplate, and evaluate arguments for and against alternative theoretical positions. Only 16% of Kuhn's participants consistently generated genuine evidence for their own theories. Many participants simply elaborated their theories, and some (about 30%) generated what Kuhn called pseudoevidence, a descriptive example that merely elaborated the theory, which was taken to be true. Similarly, only about one-third of Kuhn's participants consistently generated alternative theories, and were consistently able to generate a counterargument either to their own or to an alternative theory. Adolescents and older adults performed worse than young adults, and performance covaried with educational level.

Subsequent research has generally yielded results consistent with these findings. Brem and Rips (2000) argued that the abilities of Kuhn's participants might have been underestimated, because they had no access to empirical data relevant to evaluating the complex social problems in question. When prompting participants to imagine the strongest supporting evidence one could provide for a given theory, Brem and Rips found genuine evidence production in 68% of their participants. Still, adults did not reach ceiling-level performance. Similarly, Barchfeld (2008) found that young adults could be helped to think of genuine evidence to support their theory, but only 50% of the sample ($N=151$ 22-year-olds) developed arguments based on empirical evidence even after a series of very specific prompts (Bullock, Sodian, & Koerber, 2009).

Judging the validity of an argument does not seem to be easier than producing evidence-based arguments. Barchfeld and Sodian (2009) developed an argument evaluation inventory in which children, adolescents, and adults were asked to rate the quality of arguments rather than to spontaneously generate them. Theories and evidence were modeled after the interview procedure in Kuhn (1991). For example, the theory was that criminals return to crime because of poor socioeconomic conditions (unemployment and poverty), and the "evidence" to be evaluated was a case of theory elaboration, a case of pseudoevidence (e.g., "If somebody is released from prison, nobody would give the person a job because the employer will never be sure that the person will be trustworthy. Thus, to earn money when released from prison there is nothing to be done but to become criminal again") or a case of genuine evidence as in Kuhn (1991) (e.g., "Get some criminals and give them a job and compare them with those who did not find any occupation and see how long it would take both groups to become criminal again"). In a sample of 11-year-olds, 15-year-olds, and young adults, only about half of the adult university students consistently rated valid evidence-based arguments higher than flawed arguments or cases of theory elaboration. No other group showed a consistent pattern of ratings on this task. The findings from these two studies demonstrating that the evaluation of arguments is of similar difficulty as the generation of arguments suggests that making a theory an object of reflection, and evaluating evidence with respect to it, poses a genuine conceptual problem even to many adults.

Why is it so difficult to reason about causal theories? Informal reasoning has been related to epistemological understanding both conceptually and empirically (Kuhn & Weinstock, 2002; Weinstock & Cronin, 2003). The development of epistemological understanding has been characterized as a sequence of levels, from a realist or absolutist epistemological stance (commonly held in childhood), through multiplism (in adolescence) toward evaluativism (in educated adults). Realism is characterized by a failure to differentiate beliefs or theories from reality, since assertions are conceived of as copies of external reality. Absolutism does entail a distinction between true and false beliefs. However, knowledge is seen as objective, as located in the external world, and knowable with certainty. Similarly, on an absolutist level, reasoners (e.g., in Kuhn's argumentation task) are unable to conceive of alternatives to their own view, and they do not realize that their own theory could be false. On the multiplist level, knowers are aware of the uncertain and subjective nature of knowing, but they typically believe that assertions are personal opinions, freely chosen and accountable only to their owners. On this level of argumentation, participants may conceive of alternative views, but they lack an understanding that alternative theories make conflicting claims about the truth, and that these claims can be empirically evaluated. In contrast, the evaluativist level is characterized by acknowledging uncertainty without forsaking evaluation. Divergent viewpoints are understood as emerging from construction and interpretation, not simply from lack of access to factual information. Consequently, standards of justification and rational argument are seen as necessary to evaluate such constructions. No simple way of deciding between truth and falsehood can be applied, rather a complex and multifaceted process of evaluating theories and evidence emerges from an evaluativistic appreciation of knowledge construction. Only at this level, theories can be successfully differentiated from evidence in argumentation. By relating the levels of argument observed in her empirical study to levels of epistemological understanding, Kuhn (1991) found that almost half of adult participants were on the absolutist level, and less than one-third both on a multiplist level and in the evaluativist category.

One problem with this account of epistemological development is that it conflicts with findings from recent research on Theory of Mind development. By the age of about 6 years, children not only differentiate beliefs from reality but also understand that the same event will be interpreted differently by different people according to their social stereotypes (Pillow & Weed, 1995). Ample evidence has revealed children's growing understanding of the mind as an active interpreter of information during the elementary school years (Chandler & Carpendale, 1998; see Sodian, 2005, for a review). Thus, realism and absolutism do not appear to be adequate descriptions of preadolescent children's epistemological understanding. Moreover, recent research on the early development of scientific reasoning has yielded evidence for a basic understanding of the relation between beliefs and evidence in elementary school age (Zimmerman, 2007). For example, young elementary school children distinguish between producing a positive effect and testing a hypothesis and choose a conclusive over an inconclusive test (Sodian, Zaitchik, & Carey, 1991). Thus, it would appear that children in elementary school age should be able to reflect on alternatives to a causal theory (as long as they understand the theory), and that they should possess a basic understanding of a theory being subjected to empirical testing. However, the empirical studies indicate an inherent failure to do so even in adolescents and many adults.

Better understanding of the difficulties involved in argument generation and evaluation appears to require an analytic framework that provides a basis to distinguish between different levels of theory–evidence differentiation, rather than just diagnosing a failure in differentiating theories from evidence. For example, it is possible that participants understand in principle that evidence can be brought to bear on causal theories, but they have an overly simplistic idea of how to "prove" a theory right or wrong. One reason may be a failure to differentiate between simple beliefs and theories. A theory is a conceptual framework consisting of a set of interrelated beliefs and specifying an explanatory framework for a domain of phenomena. A full, explicit metaconceptual understanding of theories in the sense of explanatory frameworks has been shown to be extremely rare even in adults. However, a partial understanding of alternative explanations emerging from competing theories was shown even in some children and most adolescents (Bullock et al., 2009). Such a partial understanding can be sufficient to support flexible thinking about alternatives, but it may not be sufficient for theory evaluation.

An analytic framework that distinguishes between an understanding of simple beliefs and an understanding of theories was developed by Carey, Evans, Honda, Jay, and Unger (1989) for the analysis of Nature of Science understanding (see also Thoermer & Sodian, 2002). In this chapter, we argue that such a framework can productively be applied to the analysis of theory evidence differentiation in argumentative discourse.

8.3 Levels of Theory–Evidence Differentiation

The framework (Carey et al. 1989; see also Thoermer and Sodian 2002) distinguishes between three levels of theory–evidence differentiation: no differentiation (Level 1), differentiation at the level of simple beliefs (Level 2), and advanced differentiation implying an understanding of interpretive frameworks or theories (Level 3) (see Table 8.1 for an overview).

On Level 1, ideas or theories are either completely neglected or confounded with facts, data, or evidence. When asked, for example, what the goals of science are, participants at Level 1 typically respond in terms of concrete activities (making things work; Level 1a) or in terms of simple collection of facts which from the participant's point of view exist objectively (1b). No appreciation is found at this level for the role of ideas or theories in the (scientific) inquiry process. Applied to the context of argumentation, Level 1 understanding captures different types of failures to differentiate theory from evidence. Conceiving of a theory as a prescription to achieve positive effects or to prevent negative ones (1a), mere theory elaboration (1b), or collection of facts without reference to theory (1b). Thus, Levels 1a and 1b correspond to realism and absolutism in the literature on epistemological beliefs, in the sense that there is no distinction between ideas, theories, and evidence.

On Level 2, ideas or theories are differentiated from evidence or data such that individual claims are related to evidence to support or refute a claim. Level 2 answers typically show an understanding of the notion of testing beliefs and of constructing explanations. Thus, the awareness that alternative explanations for a phenomenon are possible is one aspect of Level 2 thinking, and the notion of critically evaluating such explanations is another aspect. However, the appreciation of explanation and evaluation is typically limited to the testing and evaluation of individual hypotheses. There is no understanding of theoretical coherence between different hypotheses or of the testing of theories as a multi-step, cumulative procedure of hypothesis generation and evidence evaluation. In the context of argumentation, Level 2 answers provide genuine evidence for or against a claim. Distinctions can be made between different types of evidence and levels of evidence quality. Typically, Level 2 subjects tacitly assume that a theoretical claim can be proven right or wrong by a single test or a single piece of evidence. They do not anticipate a series of further questions emerging from a single test, nor do they anticipate counterargument and conflict of interpretation between proponents of alternative theories. While they can conceive of alternatives to their own theory, they either believe that deciding between the alternatives is straightforward, or they believe that to bring evidence to bear on the conflicting viewpoints at all is impossible.

To capture a fragile and implicit understanding of some Level 2 points, an intermediate Level 1.5 between Levels 1 and 2, was introduced. For example, participants may outline an empirical test for their theory, but they may not be able to specify how the proposed test generates evidence relevant to a specific theoretical claim, or they may cite pieces of evidence relevant to evaluating a theory, but fail to see the shortcomings of their proposed tests. Thus, on Level 1.5, participants show at least an implicit differentiation of theory and evidence, but the differentiation may be incomplete or not explicitly articulated.

On Level 3, there is an appreciation of interpretive frameworks or theories, and of the cyclical and cumulative process of theory evaluation. With respect to Nature of Science, this level of understanding is characterized by a constructivist view of the scientific inquiry process. The role of theories in guiding research questions, the choice methods, and the interpretation of findings is explicitly appreciated. Similarly, with respect to informal argumentation, a Level 3 understanding is characterized by an understanding of everyday theories as coherent systems of beliefs, as opposed to simple beliefs. While people tend to recover from simple false beliefs by gaining access to reality, recovery from false beliefs embedded in theories is typically not achieved by access to information. Rather, theories function as frameworks guiding the interpretation of new evidence or information. Therefore, Level 3 answers are characterized by an understanding of the complexity of theory evaluation and the process of argumentation as guided by theoretical frameworks.

The present distinction between different levels of theory–evidence differentiation implies that different levels of conceiving of and evaluating alternative ideas can be distinguished. Thus, on Level 2, we would expect an understanding of alternatives (multiplism), but also some understanding of "testing" ideas (evaluativism), even if this understanding may be naïve and inadequate. Level 3 reflects progression with respect to both understanding theories as belief systems and understanding the process of evaluating theories. Note, however, that the distinction between different levels does not imply that participants' reasoning can always be characterized as clear-cut Level 1, 2, or 3 reasoning. The levels model is not a stage theory that makes a priori assumptions about developmental synchrony.

Empirical studies on Nature of Science and theory understanding in different age groups show that Level 3 understanding is almost never attained in lay adults' reasoning about the Nature of Science, and is rare even among science graduate students (Thoermer & Sodian, 2002). Similarly, most adults do not reflect about alternative theories (such as a witchcraft theory of disease) on Level 3 (Bullock et al., 2009). Even an explicitly articulated Level 2 understanding is rare among adolescents and adults (Bullock et al., 2009). However, instruction is effective even in children: a Nature of Science instructional unit had effects on the level of understanding in fourth graders, who showed a clear Level 1 understanding in the pretest, and were able to articulate some Level 2 points in the posttest (Grygier, 2008; Sodian, Jonen, Thoermer & Kircher 2006; Sodian, Thoermer, Kircher, Grygier & Günther 2002). Thus, elementary school children appear to possess some implicit differentiation of theory and evidence which they learn to articulate through an instructional unit. This level of processing is consistent with Theory of Mind research (as outlined above), which indicates that diversity of interpretation and the logic of hypothesis testing is understood in the elementary school years in supportive contexts. Nature of Science interviews lack contextual support and require an abstract understanding of difficult epistemological points. In contrast, theory-based argumentation is contextualized and uses domains in which participants have rich, intuitive knowledge. No abstract knowledge about the logic of experimentation is assessed, but participants are prompted to generate intuitive ideas about ways to test and defend their views. Therefore, we expect to find a beginning ability to differentiate theories from evidence in elementary school children's argumentation which we hope to capture with the levels system.

8.4 An Empirical Study of 6- and 11-Year-Old Children's Skills of Argument

To test the applicability of the analytic framework outlined above to the context of informal argumentation, we coded data from a study of children's skills of argument with the levels system. In an interview modeled after the tasks designed by

Kuhn (1991), children ($N=49$ 6-year old; $N=60$ 11-year-old) were asked to explicate their intuitive theories about the causes of misbehavior (aggressiveness) in children to generate evidence relevant to evaluating their theory, to give an alternative theory, and to provide evidence supporting the alternative theory (see Appendix for an outline). Note that the first question asking for evidence to support their own theory was followed by more specific prompts. Children were eventually asked to imagine they were a scientist conducting a study about the causes of aggressiveness in children (prompted evidence): how would they then gather evidence relevant to testing their theory?

The results indicated that children of both age groups readily offered their views when asked for their own theory about the causes of misbehavior in children. Only one child of the group of the 11-year-olds and only three children from the kindergarten group were not able to generate a plausible theory.

Since the achievement was better when asking the children to pretend to be a scientist, the frequency of responses coded at each level for this section and for the level gained when generating an alternative theory was separated for the two age groups (Table 8.2). Not surprisingly, a substantial proportion of "don't know" (ignorance) answers were given in the younger age group in each section of the interview. However, more than two-thirds of the 6-year-olds and over 80% of the 11-year-olds provided codable answers when asked to generate evidence relevant to their own theory (with prompts) and an alternative theory. As can be seen from Table 8.2, the majority of the 6-year-olds and 35% of the 11-year-olds gave Level 1 answers when asked to generate evidence. Elaborating their own theory was one of the types of Level 1 answers given with some frequency, but not the most frequent one (7.0% in 6- and 4.9% in 11-year olds). Frequent types of Level 1 answers were facts or observations vaguely related to instances of aggressive behavior in children with no particular relation to the theory (e.g., Theory: Naughty peers make children aggressive. Evidence: "Who knows, maybe the child is playing computer games all the time"). This type of answer was found in 57.1% of the Level 1 answers of the 11-year-olds and in 38.4% of the 6-year-olds. Also frequent were accounts of possible measures to prevent aggressiveness in children, for example, telling the child not to do so (23.1% of the Level 1 answers in the 6-year-old group and 38% in the 11-year-olds). Level 1 answers could be distinguished from Level 1.5 answers (4% in 6-year-olds, and 58% in 11-year-olds). On Level 1.5, children provided empirical data or facts of some relevance to testing their theory, or they suggested a method of gathering such data, for example, watching aggressive children on the playground with a hidden camera. Some children (8.4% in 11-year-olds) cited cases of covariation between the proposed cause and the outcome (e.g., a classmate being envious of other children having expensive clothes and also being aggressive as evidence for the theory that jealousy causes aggression). Most children, however, merely reflected upon a possible method of gathering relevant evidence. Their proposals generally showed a credulous belief in the immediate access to objective facts (e.g., "I would ask aggressive children why they do this": 45.8% 11-year-olds and all of the 6-year-olds). Neither 6-year-olds nor 11-year-olds gave answers on Level 2 or higher, even when prompted.

One reason for the difficulty in thinking of evidence relevant to evaluating one's own theory might be an inability to conceive of alternatives to this theory. In fact, Kuhn (1991) found that generating evidence and producing an alternative to one's theory were about equally difficult and intercorrelated in adolescents and adults. However, in this study, children performed at a higher level in generating an alternative than in generating evidence. Six-year-olds (35%) and 11-year-olds (63%, 29% at Level 2) gave answers on Level 1.5 or higher when asked for an alternative theory, but only 4% of the 6-year-olds and 58% (0 at Level 2) of the 11-year-olds gave answers when asked to generate evidence (see Table 8.2). Children's answers were scored at Level 1.5 when they provided an alternative cause for aggression without any reasoning about possible mechanisms (e.g., the original theory was that children are aggressive toward peers they do not like, and the alternative was that they are aggressive because they are being frustrated). The answers were coded at Level 2 when there were plausible justifications for an alternative causal mechanism linking cause and effect (e.g., the original theory was that parents are treating them wrongly, either spoiling them or treating them harshly, and the alternative was that "it" may be genetically transmitted). Children's answers coded at Level 1 mostly failed to distinguish between the original theory and an alternative, or they gave an account of measures to prevent aggression rather than developing a theory about its cause.

In sum, the present findings indicate that some 6-year-olds and the majority of 11-year-olds possess the cognitive flexibility required to generate an alternative to their own theory about an everyday phenomenon. Thus, there is some metaconceptual awareness of causal theories at an early age. At least some children are able to represent their own original theory and at the same time to represent an alternative causal account without confounding the two. However, they often fail at providing empirical evidence relative to either the one or the other theory. Thus, the ability to represent alternative causal theories might be necessary, but it does not seem to be a sufficient precondition for generating evidence relevant to theory evaluation.

8.5 Cognitive Flexibility and Epistemological Understanding: A Developmental Puzzle?

We began with the puzzling observation that, on the one hand, thinking of alternatives and understanding the truth functionality of beliefs emerge in cognitive development around the age of 4 years, with close interrelations between these two components of cognitive flexibility. On the other hand, the inability to conceive of alternatives to one's own causal beliefs about everyday phenomena and the lack of ability to critically evaluate one's own ideas or theories appear to persist in adulthood. We argued that the current analysis of these phenomena in terms of levels of epistemological development (absolutism, multiplism, and evaluativism) is flawed (or insufficiently elaborated), given that the Theory of Mind literature and research on scientific reasoning indicate an understanding of the interpretive mind and a basic understanding of the logic of hypothesis testing in elementary school children. We developed an analytic framework derived from work by Carey et al. (1989) on Nature of Science understanding for a more fine-grained distinction between levels of theory–evidence differentiation and applied this framework to the analysis of data on 6- and 11-year-old children's skills of argument.

Little evidence was found for a *pervasive* failure in children to understand that evidence is relevant to evaluating causal beliefs or to conceive of alternatives to one's own theory. The levels system was shown to be useful in analyzing different types of problems in differentiating theories from evidence and in identifying precursors to a full differentiation. Interestingly, children's main source of failure to provide evidence for their theories was *not* theory elaboration. Rather, children tended to search for facts or observations in the outside world but often failed to relate these facts to their theory, or they provided prescriptions for changing the phenomenon (Level 1 answers). On Level 1.5, children searched for theory-relevant observations or tests, but they were guided by naïve conceptions about the kinds of evidence that might be relevant to evaluating such theories and the way to obtain such evidence. The finding that both 6-year-olds and 11-year-olds tended to believe in a direct and unproblematic access to knowledge is consistent with a large body of literature on children's epistemological development (see Carey & Smith, 1993, for a description of the "knowledge unproblematic" epistemological stance). However, the present findings indicate that the naïve belief in a direct and unproblematic access to the truth is not necessarily based on absolutism, that is, the failure to conceive of alternatives. Rather, some 6-year-olds and most 11-year-olds had no difficulty in conceiving of alternatives to their own theory in a familiar domain. Most children gave perfectly distinguishable and plausible theoretical accounts, such as a nature versus nurture theory, or a "frustration causes aggression" versus "aggression is inborn" theory. This is remarkable since the responses required rich domain-specific causal knowledge. The ability to think of alternative causal accounts for a phenomenon is certainly an indicator of cognitive flexibility at an advanced level. The close association between the development of cognitive flexibility and epistemological understanding observed on the level of simple beliefs does not appear to reemerge at the level of causal theories. Rather, children appear to develop cognitive flexibility with respect to causal beliefs or theories before they acquire an advanced understanding of the evidence relevant to evaluating a causal theory. Training or experience in developing alternatives to one's own views is possible to have positive effects on an understanding of the theory–evidence relation, because defending one's views is obviously necessary when challenged by alternative views. Alternatively, it is possible that children (but also many adolescents and some adults) lack an intuitive understanding of the kinds of evidence (i.e., predominantly covariation data) that can be brought to bear on causal theories, and that such methodological issues should be directly addressed in educational settings.

The present (preliminary) findings are consistent with the view that elementary school children possess an understanding of the interpretive mind that enables them to think of alternative interpretations. They are less consistent with predictions derived from the scientific reasoning literature, indicating an understanding of the logic of hypothesis testing. Both 6- and 11-year-olds were remarkably poor in generating theory-relevant empirical tests, even though the 11-year-olds showed a principled understanding of the relevance of empirical data. Readers should note that the present task required an understanding of testing a theory, rather than testing a simple hypothesis. In the scientific reasoning literature, the evaluation of rich, real-world theories by laypersons has not been studied. Prompts designed to help participants to derive a testable hypothesis from their theory could possibly help them in generating evidence. Future research should introduce specific prompts to reduce cognitive load to test for children's and adolescents' conceptual differentiation of theory and evidence independently of processing demands.

With respect to models of epistemological development, the present findings are inconsistent with profound realism or absolutism in children. The ability to conceive of alternatives while being unable to critically evaluate these could arguably be an early characteristic of multiplism. Most participants, however, clearly believed in ways to distinguish between alternative views by means of empirical evidence rather than arguing that "anything goes, it's just opinions." Yet, they often did exhibit a belief in a direct and unproblematic access to the truth, for example, the truth about aggression to be determined by interviewing aggressive children about the causes of their behaviors. Such answers could reflect lack of domain knowledge (psychological knowledge) as much as epistemological naiveté. In sum, a more differentiated description of epistemological understanding appears to be needed that captures concepts of beliefs (and belief systems) as well as concepts of evidence generation and testing of beliefs.

Perspective taking and thinking of alternatives emerge in close association with Theory of Mind development in preschool age. In elementary school age, perspective taking does not appear to be limited to the distinction between simple beliefs and reality. Rather, advanced forms of perspective taking, involving the representation of competing causal explanations of phenomena, appear to emerge in middle childhood. However, the ability to generate such theories does not appear to imply, from the start, an adequate understanding of theory evaluation. Further research is necessary to assess the extent of a dissociation in middle childhood and adolescence between two dimensions of cognitive flexibility that are closely intertwined in preschool age.

Appendix

Table 8.1 Levels of theory evidence differentiation

Level 1: No differentiation
Ideas or theories are either neglected or confounded with facts, data, or evidence
Level 1a. Producing effects (concrete activities), making things work. No representations of ideas, beliefs, or theories
Level 1b. Objective collection of facts not guided by beliefs or mere elaboration of theory without any reference to data or evidence
Level 1.5: Implicit (tentative) differentiation of theory and evidence
Rudimentary understanding of testing beliefs, often incomplete and not explicitly articulated. Participants may outline an empirical test for their theory but may not be able to specify how the proposed test is supposed to generate evidence relevant to a specific theoretical claim, or they may cite pieces of evidence relevant to evaluating a theory but fail to make the relation between these pieces of evidence and theory explicit.
Level 2 : Theory–evidence differentiation at a basic level
Ideas or theories are differentiated from evidence or data such that individual claims are related to evidence to support or refute a claim. Answers typically show an understanding of the notion of “testing beliefs” and of “constructing explanations.” However, these notions are limited to the testing and evaluating of individual hypotheses. No appreciation of a theoretical coherence exists between different hypotheses or of the testing of theories as a multi-step, cumulative procedure of hypothesis generation and evidence evaluation. Answers provide genuine evidence for or against a claim.
Level 3: Theory–evidence differentiation at an advanced level
An appreciation of interpretive frameworks or theories and of the cyclical and cumulative process of theory evaluation is made explicit. Theories are understood as coherent systems of beliefs. Theories function as frameworks guiding the interpretation of new evidence or information. Therefore, Level 3 answers are characterized by an understanding of the complexity of theory evaluation.

Table 8.2 Frequencies of responses coded on each level on the item “prompted evidence” and in the generation of alternative theories in percent

	6 years		11 years	
	Prompted evidence	Alternative theory	Prompted evidence	Alternative theory
Ignorance	41.7	34.7	6.7	18.6
Level 1	54.2	63.3	35.0	18.7
Level 1,5	4.2	30.6	58.3	33.9
Level 2	–	4.1	–	28.8

Table 8.3 Questions of the interview

Description	Question
Theory generation: Question eliciting the participant's theories regarding the cause of the phenomenon	
Generation of original theory	What do you think, why are some children aggressive, although they are disciplined all the time?
Evidence for original theory: Questions in which the subject was asked to justify the theory by providing supporting evidence	
Spontaneous evidence first	Imagine, you have to convince another child that your view is right, that XXX (original theory of the child) is the main cause, what evidence would you give to try to show this?
Spontaneous evidence second	What would you tell the other child, how would you convince the child that you are right?
Spontaneous evidence third	Is there anything someone could say or do, that this is why some children are aggressive all the time?
Prompted evidence: Extra question, a request to develop a scientific investigation in order to develop objective empirical evidence.	Imagine you are a social scientist and want to conduct a scientific investigation. You want to prove that your cause XXX (original theory of the child) is the main cause why some children behave aggressively against others. How would you design your study, what would you do?
Contradictory positions: Questions in which the child was asked to generate a line of counterarguments	
Alternative theory	What might Maxi/Lena say is the major cause why some children behave aggressively against others?
Evidence for alternative theory	How could Maxi/Lena prove that he/she was right and you were wrong?

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Chapter 9
Medical Trainees' Epistemological Beliefs and Their Cognitive Flexibility

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9.1 Introduction

Medical students acquire considerable medical knowledge throughout their training. Once they are practicing, translating this (mostly theoretical) knowledge into usable knowledge on a daily basis is an immense challenge (Schmidt, Norman, & Boshuizen, 1990; Schmidt & Rikers, 2007). A good illustration of this process is the medical knowledge that students acquire in relation to diabetes. During their training, a considerable amount of time will be attributed to teaching students the pathophysiology of diabetes, its signs and symptoms, its complications, and how to diagnose and treat it. This information is usually passed on by authorities ("professors") in the field, who are familiar with the disease and the existing related literature. Whereas such teaching departs from the disease "diabetes," the practicing student (or trainee) will be confronted with a patient. As a result, the first challenge for students will be to inverse their knowledge so that they can, based on the patient complaints (e.g., thirst and weight loss), come to a diagnosis in an efficient way. A second challenge will be to draw a personalized and realistic management plan for every individual patient. Coexisting diseases as well as the patients' motivation are crucial in setting treatment goals. A compromise taking into account these factors may as a result diverge from ideal end points learned during training. When faced with colleagues (other GPs, practice nurses, etc.), the trainee will be

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required to adopt a third approach toward the same knowledge on diabetes. Questions come to the fore, such as “How can we organize our practice in order to improve the outcome of the treatment of the diabetes patients?,” “How can we organize our practice to be more efficient at screening for diabetes complications?.”

Several authors have recently argued that medicine is a domain in which knowledge has a complex and nonlinear nature, that is, it requires careful application tailored to the particular characteristics of the situation (Burger, 2001; Sweeney & Kernick, 2002). As illustrated in the above example, general, straightforward, and simplistic rules are rarely usable in practice (Sweeney & Kernick, 2002). Coulson, Feltovich, and Spiro (1997) have similarly illustrated how the most frequently used clinical or basic scientific approach (grounded on linear assumptions) to medical diagnosis and treatment can lead to misconceptions and thus to the inadequate treatment of patients with hypertension. Working in domains with complex content and irregularity of knowledge application (so-called ill-structured domains) requires cognitive flexibility (Spiro & Jehng, 1990). This term was defined by Spiro and Jehng (1990) as

> the ability to spontaneously restructure one’s knowledge in many ways, in adaptive response to radically changing situational demands (both within and across knowledge applications) (p. 165).

Some authors have referred to the need for more cognitive flexibility in medical settings and they underline the importance of fostering cognitive flexibility during medical training (Coulson, Feltovich, & Spiro, 1989; Heath, Higgs, & Ambruso, 2008). One of the prerequisites for cognitive flexibility is to possess sophisticated epistemological beliefs. That is, individuals believing that knowledge has a more complex and evolutional nature and that knowing is justified by an elaboration of several arguments are expected to use their knowledge more efficiently in different contexts than individuals with dualistic beliefs (Jacobson & Spiro, 1995; Spiro, Feltovich, & Coulson, 1996).

In this chapter, we explore three theoretical propositions regarding EB and cognitive flexibility pertinent to our study of trainee general practitioners in Belgium. First, we assess whether the beliefs trainees hold about knowledge and knowing consist of different dimensions, which are stable across different medical domains. We investigate the beliefs with reference to a study we performed on the nature of medical trainees’ EB.[1] Second, we examine the proposition that trainees with sophisticated EB lead to high levels of cognitive flexibility. The third and final proposition for consideration states that in order to foster cognitive flexibility, medical curricula should be revised to encourage trainees to reflect upon the nature and structure of knowledge.

[1] These are master-after-master students who had completed their 6-year basic medical training and who were enrolled in a 2-year programme of general practice training.

9.2 Statement 1: The Beliefs Medical Trainees Hold About Knowledge and Knowing Consist Out of Different Dimensions Which Are Stable Across Different Medical Domains

Although several frameworks for studying EB have been developed based on Perry's initial work in the 1960s, Schommer's work has been a catalyst for the exploration of the nature and role of individual's EB (Perry, 1968; Schommer, 1990). Using questionnaires, Schommer and others identified a number of separate dimensions of EB (or separate beliefs), which seem to develop independently from one another (Buehl, 2008). The content of the dimensions has varied considerably in the different research projects, but can be categorized into two major groups: beliefs in the nature of knowledge (structure and certainty of knowledge) and beliefs in the nature of knowing (justification process and source of knowledge). The beliefs are usually described on a scale ranging from dualistic beliefs (belief that knowledge is simple, unchangeable, etc.) to sophisticated (belief that knowledge evolves, has a complex structure, etc.) (Hofer & Pintrich, 1997; Schommer, 1990).

EB have been the focus of a small number of studies in the medical domain. In these research projects, medical students and trainees as well as physicians have been demonstrated to hold EB about medical knowledge (Knight & Mattick, 2006; Lonka & LindblomYlanne, 1996; Peña, 2007; Peña, Paco, & Peralta, 2002; Roex, Clarebout, Dory, & Degryse, 2009). However, the exploration of the actual nature of these EB has not yet been explored. Hence, we would like in this first section to explore in more detail the proposition that the beliefs trainees hold about knowledge and knowing consist out of different dimensions which are stable across different medical domains. Whether medical trainees' EB develop as one entity or whether they consist out of different, separately evolving dimensions (beliefs) remains unclear. Conflicting observations in other domains about the uni- or multidimensional nature of EB stimulate investigation into how these dimensions occur in medical trainees. The second question addresses the domain specificity of EB related to medical knowledge. We believe that this second question is a particularly complex one to assess, given a number of factors specific to the medical arena. Medicine is traditionally perceived as constituting one domain. One could claim that it is steered by one ontology. The evidence-based medicine (EBM) approach has largely infiltrated medical curricula, and it is advocated to have a great influence on medical practice. The same sets of clinical epidemiological rules dominate practice guidelines on different topics. On the other hand, medicine is very broad in scope. The curriculum is divided into different system-related specialties, for example, cardiology, urology, and orthopedics. Such arguments give rise to the suspicion that individuals' EB may be domain specific, that is, they might vary depending on the medical specialty or "subdomain" concerned.

Moreover, with regard to both medical expertise research and medical reasoning, knowledge (organization) and not the reasoning abilities themselves have been demonstrated to play a crucial role in successfully solving clinical problems.

This phenomenon has been called case specificity (also content specificity) (Elstein, Shulman, & Sprafka, 1978). Clarity about the dimensionality and domain specificity of EB is important for the further investigation of EB and their potential role in medical education and medical performance. One might infer from domain specificity that the measure of subdomain EB would provide insights for that particular subdomain, and that broad sampling would be required across the whole domain of medicine to assess individual's beliefs about medical knowledge. Domain specificity could potentially indicate that more sophisticated EB acquired in one instructional environment are not transferable to other (learning) settings. This domain specificity could have far-reaching implications for the design of the curriculum and to the daily practice of a physician. If EB are domain specific, they may not be transferable from one clinical problem (e.g., management of a patient with breathing difficulties) to a problem related to another domain (e.g., management of a patient with a swollen foot).

For these reasons, we developed the present study aimed at identifying the dimensions of medical trainees' EB. Specifically, we examined whether trainees' EB about knowledge of the urogenital (UG) tract were different than their beliefs about the musculoskeletal (MS) tract (Roex, 2010).

Few authors have endeavored to study medical trainees' (or students') beliefs. Lonka and Lindblom Ylanne (1996) administered questionnaires that were domain general, thus, not focusing on the discipline of medicine. In another study, auto-diaries were used, which proved to be a valuable instrument but very labor intensive. Moreover, they were not the most appropriate instrument to answer the research questions in the study (Knight & Mattick, 2006). To avoid critiques raised on general statements, we decided to use concrete and clinically embedded statements. Every item consisted of a patient problem which was representative of the day-to-day practice of a general practitioner (Leach, Millar, Ryder, & Sere, 2000). By using this design, we aimed to make the statements as concrete as possible for the student (and thus to avoid having to ask the trainees to express generic beliefs). By using statements which were very closely linked to daily practice, we also hoped to recall enacted (used in practice) beliefs rather than professed (stated) beliefs (Tobin & McRobbie, 1997). We constructed two parallel questionnaires each containing 36 items. For each item in the UG tract, a corresponding, identical item was provided on the MS tract (total of 72 items). Both items expressing dualistic beliefs, as items stating relativistic beliefs were used (see, e.g., Table 9.1).

A rigorous, stepwise validation protocol (exploratory focus group study, expert and student validation according to the "cognitive interview" method, and pilot study) was followed in order to ensure the validity of the questionnaire for the purposes of the study (for a detailed report on the questionnaire construction, see Roex, 2010). Trainees ($n=364$) participated in the study. We factor-analyzed the items on both questionnaires without the use of subscales (in line with, among others, Cano, 2005; Kardash & Howell, 2000 and Schommer-Aikins, Duell, & Barker, 2003). Only one factor was identified. For each item in the UG tract, the corresponding item from the MS tract also linked to the same factor. All of these items referred to the justification for knowing. The resulting scale (which we called the JUMKUM

Table 9.1 Examples of items used in the questionnaire

MS	UG
Because, to date, imaging is the most appropriate diagnostic tool for traumatic bone fractures, this will remain so in the future	Because to date, microscopic investigation is the most appropriate diagnostic tool for *urinary tract infection*, this will remain so in the future
There is overwhelming evidence (based on RCTs and systematic reviews) to prove that exercise and physiotherapy reduce pain in patients with *gonarthrosis*. Nevertheless, it is very likely that other studies will change these findings	There is overwhelming evidence (based on RCTs and systematic reviews) to prove that 5-alpha-reductase inhibitors abate symptoms in patients with *benign prostate hypertrophy*. Nevertheless, it is very likely that other studies will change these findings

scale, referring to JUstification for Medical Knowledge in the Urogenital and Musculoskeletal tract) contained 20 items and was assessed to have a high reliability (α=0.88). The results implied that medical trainees have a "generic" way to justify their knowledge within the UG and the MS tract and possibly within the whole medical domain. As for structure and certainty of knowledge, no coherent beliefs were found. This result raised the question whether trainees actually possessed beliefs about the nature of knowledge. However, in a previous study using focus groups, we found that medical trainees did express such beliefs (Roex et al., 2009). The impossibility for the factor analysis to link items to the nature of knowledge factor does not necessarily imply that trainees lack such beliefs. Rather, the finding suggests that these beliefs might be case specific (also called content specific). The conclusion follows that the particular content of the medical problem, and not the domain topic, determines the belief in the structure and certainty of knowledge. For example, although both items were classified within the same domain (in the example that is the UG tract), the way trainees rated the statement about the certainty of the guidelines for the treatment of diabetic nephropathy (i.e., kidney diseases) had no predictive value for the way they rated the statement about the certainty about the treatment of benign prostate hypertrophy (i.e., prostate diseases). The finding of only coherent beliefs in the justification of knowing could be a consequence of the chosen construct of EB (EB as a set of beliefs) or an artifact of the applied methodology (i.e., questionnaire with Likert items and factor analysis). Both the underlying theoretical frameworks and the methodology influence study results. Yet, we came to similar findings using a qualitative methodology in a different study (Roex et al., 2009). Another potential explanation for these findings is the omnipresence of the evidence-based medicine (EBM) framework in medical curricula. Sacket introduced the EBM framework in an attempt to provide physicians a tool with which to critically appraise medical knowledge (Sacket, Rosenberg, Gray, Haynes, & Richardson, 1996). Over the years, EBM has pervaded the medical practice and has become, as the large number of publications testify, a goal for medical education (Shaneyfelt et al., 2006; Straus et al., 2004). EBM especially focuses on the justification process of medical decisions. Its introduction into medical curricula has likely increased trainees' awareness of the need to defend, for example, diagnostic or therapeutic choices and has made them more articulate at doing so. However, EBM does not offer a framework for reflecting on the nature of knowledge (structure and certainty of knowledge), and trainees do not seem to have (developed) generic approaches to these aspects of knowledge. Their beliefs about the nature of knowledge vary very strongly from one medical problem to another.

In other words, the results of this study were somehow surprising. Whereas the use of the questionnaire has not led to the identification of coherent beliefs in the nature of knowledge, it has shed light on trainees' coherent beliefs in the justification of medical knowledge. Moreover, these beliefs appeared stable across different medical domains.

9.3 Statement 2: Sophisticated EB Lead to Higher Levels of Cognitive Flexibility

We illustrated in the introduction how cognitive flexibility is relevant for young doctors who continuously need to apply the knowledge they possess in different (new) contexts.

In this section, we investigate, within the medical arena, the proposition that "sophisticated EB lead to higher levels of cognitive flexibility" (Jacobson & Spiro, 1995; Spiro et al., 1996). The results from examining the proposition is likely to be particularly useful to us, educators, not only by offering an insight into the factors involved in cognitive flexibility but also by providing indications of how to improve trainees' cognitive flexibility.

The Flemish postgraduate school centralizes GP training for the four Flemish medical faculties (Dutch-speaking part of Belgium). The 2-year master-after-master training (during which the trainees work full time in a practice) concludes with a certification examination that consists of three modules: an extensive written test, an objective-structured clinical examination (OSCE), and a structured oral examination (Degryse, 2003). This multi-modular structure was not only designed to assess numerous aspects of medical competence (i.e., what physicians should be capable of doing, Rethans et al., 2002) but also to increase the reliability of the pass-fail decision. The psychometric characteristics of the different components have been documented. Together they produce a high composite reliability (which is mandatory for this high stakes' licensing examination) (Degryse, 2003). Each of the tests requires candidates to adapt their medical competence to a particular context. In the OSCE, for example, the trainee is observed within the context of a realistic practice setting. Faced with a simulation patient, they have to act out how they would manage a certain situation (e.g., telling a patient that the diagnosis is diabetes and what the ailment requires of the patient). On the other hand, in the oral test, the trainee is challenged by a jury of staff members to elaborate upon certain GP-related issues (e.g., on the goals in the management of diabetes and on the consequences that this has for a practice). In other words, throughout this testing procedure, trainees' cognitive flexibility is challenged. They are required to expose the same GP competence in varying contexts with particular needs. Therefore, by looking at the way individuals perform on each of the modules could provide information about the extent to which the participants can adapt to changing situational (testing) demands.

9.3.1 Methods

9.3.1.1 Participants

Participants were medical trainees in their last year of postgraduate general practice training ($n = 117$) studying at a Dutch-speaking postgraduate school.

9.3.1.2 EB Measure

The JUMKUM scale was used as a measure for the trainees' EB on two subdomains of medicine, which are also included in the tests of medical competence. This scale was the product of the study reported in the previous section. It comprises 20 case-embedded items, which assessed the beliefs in the justification for knowing.

9.3.1.3 Measure for Cognitive Flexibility

The trainees took part in the extensive written test, in the OSCE, and in the structured oral examination (Degryse, 2003). An agreement exists in the field of medical education that not so much the test format, but rather the test content determines what is tested (Van der Vleuten, 1996). We claim that the different modules of the certification examination measure clinical, general practice–related competence, and that primarily the setup and context differ throughout the modules (Degryse, 2003). We, therefore, used it as a measure for cognitive flexibility. The scores on the separate testing modules of medical competence (each ranging up to 100%) are documented. Trainees with high cognitive flexibility could be expected to get higher correlations between scores of the several modules as well as higher total test scores than trainees with less cognitive flexibility (trainees with higher cognitive flexibility are able to adapt their performance to the context of the test).

9.3.1.4 Statistical Analysis

We generated the descriptive statistics of the variables, the participation rates, and reliabilities.

Table 9.2 Descriptive statistics for the different outcome measures

	N	Mean	SD	Maximun score	Skewness	SE	Kurtosis	SE
Oral exam	117	63.63	11.97	100%	–0.138	0.224	–0.080	0.444
Written exam	117	78.61	6.25	100%	–0.794	0.224	1.164	0.444
OSCE	117	64.83	6.79	100%	0.131	0.224	–0.314	0.444
Total test score (mean %)	117	69.03	6.05	100%	–0.370	0.224	0.573	0.444
JUMKUM score	109	65.06	10.64	100	0.345	0.231	–0.354	0.459

We then performed statistical studies comparing the four categories of trainees: trainees with *dualistic scores* (< percentile P25), with *rather dualistic scores* (P25–P50), with *rather sophisticated scores* (P50–P75), and with *sophisticated scores* (quartile groups). We computed for each of these categories the correlations between the different test modules (true and observed correlations). Due to the different pass-fail cutoff points of the three test formats (dependent on the difficulty level of each test), correlational studies were limited to computation of the Spearman's rank coefficient (thus, comparing ranking of candidates). When significant observed correlations were found, we also computed the disattenuated ("true") correlations. We compared the mean scores on the three test modules for the different categories of trainees. We also performed a χ^2 test to investigate whether the quartile groups demonstrated differences in the total tests scores. The total test score was computed as the sum of the three individual test scores. This computation was necessary to interpret high correlations between the three test formats. Students with high correlations between the test formats but low total test scores (and thus a rather low overall performance) could not be interpreted as highly cognitive flexible.

9.3.2 Results

Participation rate was very good (109 out of 117 trainees completed the questionnaires or 93.16%). The separate testing modules had moderate to very good reliabilities (Cronbach's alpha or internal consistency varying from 0.75 to 0.84). Table 9.2 provides an overview of average scores on the separate modules of the certification examination. The range of quartile groups based on the JUMKUM percentile scores were (1) dualistic, 44–57% (<P25); (2) rather dualistic, 58–64% (P25–P50); (3) rather sophisticated, 65–72% (P50–P75); and (4) sophisticated beliefs, 73–92% (>P75).

The analysis of the correlations between the scores on the test modules for each of the categories of trainees only demonstrates significant correlations for trainees with rather sophisticated beliefs (P50–P75) (Table 9.3). The latter's scores on the oral test correlate strongly and significantly with the scores on the written test as well as with the scores on the OSCE.

Table 9.3 Overview of the significant Spearman rank correlations (p value) and true correlations (*) between scores on the different test modules for each of four categories of JUMKUM scores (nonsignificant correlations were omitted)

Category based on JUMKUM score		Written test	Oral examination	OSCE
Dualistic EB <P25 ($n=27$)	Written test		0.125 ($p>0.05$)	0.118 ($p>0.05$)
	Oral examination	0.125 ($p>0.05$)		0.239 ($p>0.05$)
	OSCE	0.118 ($p>0.05$)	0.239 ($p>0.05$)	
Rather dualistic EB P25–P50 ($n=28$)	Written test		0.363 ($p>0.05$)	−0.087 ($p>0.05$)
	Oral examination	0.363 ($p>0.05$)		0.110 ($p>0.05$)
	OSCE	−0.087 ($p>0.05$)	0.110 ($p>0.05$)	
Rather sophisticated EB P50–P75 ($n=29$)	Written test		**0.474 ($p<0.01$) 0.721***	0.323 ($p>0.05$)
	Oral examination	**0.474 ($p<0.01$) 0.721***		**0.375 ($p<0.05$) 0.641***
	OSCE	0.323 ($p>0.05$)	**0.375 ($p<0.05$) 0.641***	
Sophisticated EB >P75 ($n=25$)	Written test		0.328 ($p>0.05$)	−0.118 ($p>0.05$)
	Oral examination	0.328 ($p>0.05$)		0.309 ($p>0.05$)
	OSCE	−0.118 ($p>0.05$)	0.309 ($p>0.05$)	0.118 ($p>0.05$)

* significant correlations

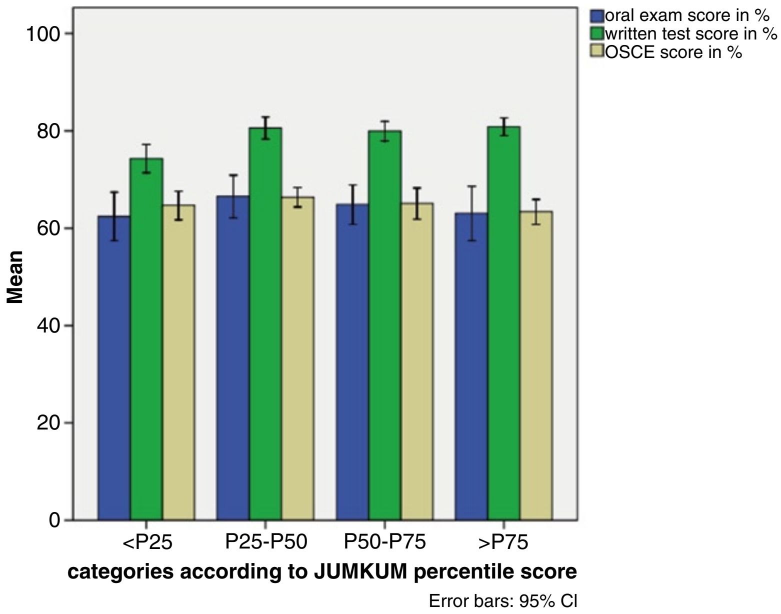

Fig. 9.1 Relation between four categories of JUMKUM scores (based on quartile scores) and the mean scores on the different modules of the final assessment procedure

Figure 9.1 suggests that, on average trainees with sophisticated beliefs did not receive higher scores for the different test modules than students with dualistic beliefs. To compute whether the mean group scores on the separate tests were statistically different, we used a parametric approach for the oral test and the OSCE, and a nonparametric approach for the written test (not normally distributed). A one-way ANOVA confirmed that the four categories of trainees based on their EB did not get significantly different scores on the oral test ($F(3, 105)=0.45$, $p>0.05$) nor on the OSCE ($F(3, 105)=1.30$, $p>0.05$). A Kruskal–Wallis analysis demonstrated a significant difference between the groups for the score on the written test, $X^2(3, 109)=16.86$, $p<0.001$. The average total test score was moderate to high ($M=69.03\%$, SD=6.05). The total test score was not statistically different in the quartile groups.

9.3.3 *Discussion*

9.3.3.1 Findings

The present study leads to surprising results. We could not confirm the hypothesis that trainees with more sophisticated beliefs about the justification for knowing demonstrate a greater ability to respond to changing situational demands. Instead, we found that trainees with rather sophisticated beliefs show greater ability to adapt to changing testing demands. In other words, trainees with rather sophisticated beliefs appeared to attain rather consistent scores on the different modules, whereas medical trainees with (rather) dualistic and sophisticated beliefs appear to perform more diversely. That is, their scores on the different modules were not correlated. Notwithstanding that trainees with rather sophisticated scores resulted in higher correlations between the different modules, their total test scores were no higher than trainees with different EB (i.e., they did not show higher levels of medical competence).

There are some potential limitations to this study that need to be considered. Trainees were categorized based on their quartile JUMKUM scores. The number of participants in each category was low, and the variation in EB scores was moderate. These drawbacks could indicate sampling anomalies. On the other hand, this study was performed in a high stakes context, and participation rate was high. More than 90% of all graduating general practitioners in Flanders (Northern part of Belgium) in 2006 participated in the study. The trainees were instructed that the EB questionnaire had no certification purposes and that the data analysis was anonymous and for study purposes only. The items were written to reduce a possible social desirability effect on the practitioners. We also found that participants had filled in the questionnaire consistently (Roex, 2010). For these reasons, we could with a high probability conclude that, although the small numbers, the sample of participants and their scores on the tests formed a good representation of the aimed population (i.e., graduating general practitioners). The test modules had varying reliabilities, which might have also influenced the data, although these were taken into account by computing the true correlations.

One explanation of our findings could be that trainees at this stage in their professional career do not posses sufficient knowledge to demonstrate high levels of cognitive flexibility. A general agreement exists in the literature on clinical reasoning that patient encounters largely influence the way doctors' knowledge base is organized (Norman, 2005; Schmidt et al., 1990). The organization of the knowledge base, in turn, determines the efficiency of clinical problem solving and might in the same way influence the trainees' cognitive flexibility. In other words, could it be possible that a critical amount of well-organized medical knowledge is required for cognitive flexibility, which trainees do not possess at this stage? A second potential explanation for our findings is that sophisticated beliefs in the justification for knowing inhibit trainees from demonstrating high levels of cognitive flexibility on this certification procedure. The lack of correlations between the scores on the different modules for trainees with sophisticated beliefs and trainees with (rather) dualistic beliefs suggests that certain test formats reward the expression of their respective beliefs more than other test formats. This finding is particularly interesting because over the last 20 years, much attention has been given to the role of EB in the way learners feel about, interact with, and learn from different instructional environments (e.g., differing class room contexts; Hofer, 2004; Kienhues, Bromme, & Stahl, 2008). Our findings also suggest that the manner in which individuals perform in different testing formats may be influenced by their beliefs about knowledge and knowing.

When interpreting these results, the purpose of the certification procedure should be considered. The test is set up in its present format to reliably identify candidate GPs who do not achieve a predefined level of competence. This has several implications. First, its purpose implies that the assessment is very reliable at a pass–fail level, but less so at ordering candidates at the lowest and highest levels of performance (Degryse, 2003). In our study, consequently, true correlations for students at those extreme levels (i.e., those with sophisticated beliefs) could have been undervalued. Second, the test procedure is constructed so that it reflects the learning goals (competencies) as described for the training of general practitioners. Experience with the final assessment procedure has taught us that the basic paradigm in medical education of "assessment drives learning" still rules (Van der Vleuten, 1996). Since its introduction, the mean scores on the different modules of the certification examination have increased year after year until they reached a plateau (Degryse, 2003). We could arguably claim that the learning goals, which are the departure point for constructing this certification test, largely influence what the students will learn. In turn, learning goals are based upon definitions of medical competence. Analyzing these definitions could therefore, as we will illustrate in the next section, shed more light on the interpretations of our findings.

To conclude this section, we are not able on the basis of our research to confirm the proposition that "sophisticated EB lead to higher cognitive flexibility." Instead, we found that medical trainees with rather sophisticated beliefs showed greater levels of cognitive flexibility than students with sophisticated or (rather) dualistic scores. These results suggest that the way individuals perform in different testing formats may be influenced by their beliefs about knowledge and knowing.

9.4 Statement 3: In Order to Foster Cognitive Flexibility, Medical Curricula Should Be Revised to Encourage Trainees to Reflect upon the Nature and Structure of Knowledge

The raison d'être of medical educators is to train students to become highly proficient medical doctors. Both teacher as well as student organizations watch over medical education to ensure this goal is met. At its launch in 1993, the European Academy for Teachers in General Practice (EURACT) has described how it aims "to foster and maintain high standards of care in European general practice by promoting general practice as a discipline by learning and teaching." The International Federations for Medical Students' Associations (IFMSA) equally strives "to prepare the medical students to meet with professional excellence the health needs of the population they serve" (International Federation of Medical Students' Associations, 2008).

This global pursuit of excellence has given rise to three major lines of research. First, it has generated research in medical expertise, which attempts to identify and understand the processes involved in becoming a good clinical reasoner and expert physician (e.g., Boshuizen & Schmidt, 1992; Dunphy & Williamson, 2004;

Elstein et al., 1978). Second, the pursuit has also inspired considerable academic investigation into how students learn and how to best design learning environments, curricula, and assessment procedures to more efficiently train medical students (Davies, 2000; Dolmans & Wolfhagen, 2004; Harden, Grant, Buckley, & Hart, 2000; Norman, 2002; Schuwirth & Van der Vleuten, 2004; Van der Vleuten, 1996). Third, it has encouraged considerable reflection on how to define both the way physicians should act in practice ("medical performance") and what physicians should be capable of doing ("medical competence") (Allen, 2005; Frank, 2005; Rethans et al., 2002; Tallis, 2006; Wass, 2006). The resulting definitions are mainly based on the insights gained in the medical expertise literature. They are important because they provide a matrix not only for designing medical curricula as well as descriptions of their goals but also for the development of certification procedures.

As we illustrated in the two previous sections, our study findings somewhat diverge from research into domains other than medicine. Medical trainees only appeared to hold coherent beliefs in the justification for knowing. We provisionally associated this with the omnipresence of the EBM approach in medical curricula, which provides a framework to reflect upon the justification for knowing without paying particular attention to the structure and certainty of knowledge. We also found that sophisticated levels of these beliefs were not linked to higher levels of cognitive flexibility. On the basis of these findings, we can hypothesize that in order to foster cognitive flexibility, medical curricula should be revised to encourage trainees to reflect upon the nature and structure of knowledge. To test this hypothesis, we will look more closely at current definitions of medical competence (which guide the content of medical curricula) using a theoretical approach. Specifically, we introduce two examples of such documents. The Royal College of Physicians and Surgeons of Canada published a definition on physicians' competence (called the "CanMEDS") which has been positively appraised and accepted as a reference work in medical settings (Frank, 2005). The EURACT has, based upon her definition of competence, compiled an educational agenda (Heyrman, 2005). It provides a framework to teach the core competencies of the discipline and is often referred to in medical settings. How then do the CanMEDS and the EURACT educational agendas approach the role of cognitive flexibility and of sophisticated EB in becoming good medical doctors?

The CanMEDS framework describes the following seven core competencies of a competent medical doctor: the medical expert, the communicator, the collaborator, the manager, the health advocate, the professional, and the scholar (see Table 9.4).

Within the doctor's role as a scholar, considerable emphasis has been placed on dedication to lifelong learning and his ability to self-assess. Medical doctors should "demonstrate a lifelong commitment to reflective learning, as well as the creation, dissemination, application and translation of medical knowledge" (The Royal College of Physicians and Surgeons of Canada, 2005, p. 21). In their detailed description of the key and enabling competencies of being a scholar, the authors refer to the need to critically appraise evidence and its sources. This could be interpreted as a reference to the need to be able to justify for knowing. As to the use of information and evidence in practice (context), their aims are limited to very general descriptions

Table 9.4 The core roles of physicians according to the CanMEDS (Frank, 2005)

Medical expert	Who aims for patient care, integrates the other six competencies into his work, decisions, etc.
Communicator	The doctor as communicator who facilitates doctor–patient relationship
Collaborator	Who works with other health-care providers
Manager	Who takes part in the health-care organization
Health advocate	Who strives for health and well-being
Professional	Refers to the respect for ethical practice etc.
Scholar	Who demonstrates a lifelong commitment to reflective learning

Table 9.5 Euract definition of general practice: (Heyrman, 2005)

Core competencies	Primary care management
	Person-centered care
	Specific problem-solving skills
	Comprehensive approach
	Community orientation
	Holistic approach
Essential application features	Contextual aspects
	Attitudinal aspects
	Scientific aspects

such as the ability to “Apply knowledge of the clinical, socio-behavioral, and fundamental biomedical sciences relevant to the physician’s specialty” (p. 10), and “Critically evaluate information and its sources, and apply this appropriately to practice decisions” (p. 21). Although the reference to the physician as a lifelong learner could be interpreted as an implicit recognition of the evolving nature of knowledge, neither the structure (interrelatedness and context dependency) and certainty of knowledge nor cognitive flexibility is reflected as such in this definition.

Within the EURACT educational agenda, no explicit record of cognitive flexibility or EB can be found (for an overview, see Table 9.5). Nevertheless, in different ways, EURACT attributes an important role to context and complexity, which can be both linked to EB as well as cognitive flexibility. The following example illustrates its contribution. Suppose Peggy, a 64-year-old female, suffers from diabetes. First, the educational agenda includes the need to be able to adopt a person-centered care which is adapted to the patients’ context and circumstances. This concern warrants physicians not to only treat Peggy’s existing disease elements (adult-onset type diabetes), but instead to treat Peggy who is suffering from diabetes. The latter includes, among others, taking into consideration Peggy’s lifestyle and her coping and motivational strategies: What is a realistic goal at this stage of her life, knowing that her husband passed away a few weeks earlier? How do we motivate her to follow a diet, knowing that she has a severe literacy problem? Second, the educational agenda advocates a comprehensive approach which refers to the need to simultaneously manage multiple complaints and pathologies in the context of the individual, the care system, the practice organization, etc. The management plan of Peggy’s diabetes needs to include strategies for treatment of the other medical problems that she has (e.g., hypercholesterolemia and hypertension). At the same time, the plan has to tune in to both the logistics of the care system and of the practice. The goal might not be feasible for Peggy to check her glucose levels four times a day if the tools for doing so are very expensive and not provided by the health-care system or by the practice. Third, the agenda also emphasizes that the physician must be able to cope with uncertainty (specific problem solving skills) and with problems that appear in an undifferentiated way (thus, not as classically presented in "prototype" pathologies).

The EURACT appears to indicate that taking into account Peggy's context and the complexity linked to her medical problems implies that the most appropriate clinical decision for Peggy may be different than the most appropriate decision for another patient in a different context (e.g., a 30-year-old obese man). This context dependency of the correctness of medical decisions is in two ways relevant to our research question. First, it refers to sophisticated beliefs in the structure of knowledge (i.e., beliefs that knowledge is relative, contingent, and contextual). Second, it indicates that possessing high levels of cognitive flexibility might help the doctor in tailoring the medical information to the particular requirements of the situation.

In summary, within these two international frameworks, references to the justification for knowing were clearly articulated, whereas beliefs in the nature of knowing and cognitive flexibility were only expressed implicitly in the EURACT competence profile. While providing only two examples cannot comprehensively address the third hypothesis, the prominence of these definitions clearly indicates that further reflection on them is necessary. Moreover, the results that emerge from the analysis of the definitions appear to be consistent with the findings from the studies in the first and second propositions. This is not entirely surprising, because these definitions of medical competence provide a matrix not only for designing medical curricula but also for the development of certification procedures. While supporting our somehow surprising results in the elaboration of the first two propositions, the definition analysis also raises questions worth investigating in this currently unexplored path of investigation. If included in descriptions of medical competence, how could the reflection on the nature of knowledge be ensured in medical curricula? What would be the effect of the inclusion on the coherency of medical trainees' beliefs about the nature of knowledge? and How can EB contribute to the design of test formats that are more appropriate for assessing such a comprehensive view on competence?' are prevailing questions in this up to now unexplored path of investigation. Notwithstanding, endeavors in this field of study should not lose sight of the most important question as to what extent such interventions help students to become better doctors.

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Chapter 10
Analyzing and Developing Strategy Flexibility in Mathematics Education

Lieven Verschaffel, Koen Luwel, Joke Torbeyns, and Wim Van Dooren

10.1 Introduction

In his foreword to Baroody and Dowker (2003), the late Hatano (2003, p. xi) argued that one of the most important issues in mathematics education is how students can be taught curricular subjects so that they develop adaptive expertise. He described adaptive expertise as "the ability to apply meaningfully learned procedures flexibly and creatively" and opposed it to routine expertise, that is, "simply being able to complete school mathematics exercises quickly and accurately without (much) understanding" (p. xi). Thus, for Hatano, the insightful, flexible, and creative use of strategies is an essential characteristic of an adaptive expert in a particular cognitive domain, such as mathematics. When using the term "expertise" in the context of mathematics education, especially at the elementary and secondary school level, it does not properly characterize learners' actual state of competence but rather a goal

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that may be reached only by some of them in the future. Expertise refers by definition to a person with extensive knowledge or ability in a particular area, a state that normally can be reached only after long, intensive, and devoted practice (Ericsson, Charness, Feltovich, & Hoffman, 2006; Hatano & Oura, 2003). Furthermore, since the notion of adaptive expertise is associated with competence in a particular area, it does not make a claim about experts' cognitive flexibility in other domains or their creativity in general (Verschaffel, Luwel, Torbeyns, & Van Dooren, 2009).

Although the constructs of adaptive and routine expertise were introduced more than two decades ago (Hatano, 1982) and terms such as adaptivity and flexibility[1] have been used with increasing frequency by educational researchers and practitioners, few attempts have been made to rigorously and systematically study adaptive expertise as a competence, and its acquisition and cultivation in the domain of mathematics education.

The three theoretical statements that we elaborate in this chapter are:

1. Strategy flexibility in mathematical problem solving consists of the efficient adaptation of one's strategies to task, subject, and context variables. Any definition or operationalization of the concept that neglects one of these variables is incomplete and therefore problematic.
2. Even though strategy flexibility is generally considered an important and distinctive characteristic of expertise in mathematics, only emerging empirical support exists for the claims that experts demonstrate more flexibility in their strategy choices than nonexperts, and that this directly and substantially accounts for their better performance.
3. Because strategy flexibility is viewed not purely as a skill but rather as a disposition (involving also knowledge, beliefs, attitudes, and emotions), teaching for strategy flexibility cannot be conceived as a method that one can begin doing after routine expertise in the use of the strategies has been taught, but should be the goal from the beginning of the teaching and learning process and in an integrative way.

In the first part of this chapter, we describe and comment on how strategy flexibility or adaptivity has been defined, operationalized, and investigated by different researchers of mathematics learning and teaching, resulting in our own working definition (statement 1). In the second part, we report empirical research that has attempted to address the empirical question of whether strategy flexibility is a critical or distinctive feature of mathematical expertise (statement 2). In the third part, we report evidence from intervention studies aimed at enhancing strategy flexibility in the domain of mathematics education, and we raise some educational considerations as to when and how to strive for it (statement 3). The research-based examples that will be used in this chapter come partly from studies that have been conducted in the context of our own research and partly from empirical studies by others.

[1] Although we are aware that some authors define the terms "adaptivity" and "flexibility" differently (Verschaffel et al., 2009), in this chapter they will be used as synonyms.

10.2 Toward a Rich, Multidimensional Conception of Strategy Flexibility

Many mathematics educators, but also cognitive and educational psychologists, define and operationalize strategy flexibility in relation to certain task characteristics. For example, Van der Heijden (1993) defined it as, "flexibility in strategy use involves the flexible adaptation of one's solution procedures to task characteristics" (p. 80). According to this view, one would call a first grader's choice flexible for solving the addition problem $2+9$ by means of a counting-on-from-larger strategy (i.e., 9…, 10, 11) rather than a counting-on-from-first strategy (i.e., 2…, 3, 4, 5, 6, 7, 8, 9, 10, 11), because a rational task analysis reveals that the former strategy requires much less counting steps than the latter one. Analogously, solving the equation $3(x+5)=12$ not by first distributing the 3 (equals the conventional solution method) but by first dividing both sides by 3 would be considered flexible because the latter strategy is arguably a shortcut for that problem (but not for others) that reduces the number of computations and/or steps needed to solve the equation (Star & Newton, 2009).

Researchers applying this view on an approach to strategy flexibility first distinguish different strategies for performing a certain type of mathematical tasks. Then, based on a rational or empirical analysis of the strengths and weaknesses of these different strategies vis-à-vis certain types of problems, they define certain problem type × strategy type combinations as flexible and others as inflexible. This approach has been used in many studies (e.g., Blöte, Van der Burg, & Klein, 2001; Thompson, 1999; Van der Heijden, 1993). For example, using sums that invite the application of flexible mental arithmetic strategies such as the sum of $18+15+5$ or $13+15-13$, Van der Heijden (1993) found that only 30% of those sums were actually computed flexibly by the fourth graders, that is, by first adding 15 and 5 or subtracting 13 from 13. Conversely, 70% were inflexibly solved by the means of the straightforward solution method whereby the arithmetic operations are computed "from left to right."

Although the ability to adapt one's strategy choices to certain predefined features of a task unmistakably touches upon an important aspect of attaining strategy flexibility in mathematics, conceiving and operationalizing strategy flexibility in terms of task characteristics alone remains, in our opinion, too restrictive. Not only in our view, but also in the view of several other researchers, as illustrated in the following quotation from Threlfall (2002), wherein the issue of strategy flexibility is addressed in the domain of mental arithmetic: "As in a number of other decision contexts, it is difficult to determine what the criteria for choice of a mental calculation method might actually be. Even though some problems do seem to suit some 'strategies' more than others, 'choice' could not be just about the number characteristics of the problem" (p. 39). Indeed, the possibility exists that for a particular subject or under particular circumstances, a strategy choice process that Van der Heijden (1993) would define as flexible could become inflexible, and vice versa. Hereafter, we consider two other types of factors to be incorporated into a more comprehensive concept and approach to flexibility or adaptivity besides task variables, namely, subject and context variables.

The first set of complicating factors, subject variables, has been intensively and systematically investigated and modeled by cognitive psychologists like Siegler (1996, 1998, 2000). Strategy choice and discovery simulation (SCADS) is Siegler's latest computer model of how children's mastery of simple arithmetic sums develops, such as 2+2 or 3+6. According to the model, whether a particular strategy (e.g., retrieval of a known number fact, a primitive or a more sophisticated counting strategy) is chosen to solve a particular item by a particular child depends on the accuracy and speed of the child's strategy for that particular item in comparison to other concurrent strategies available in the child's repertoire. Thus, SCADS always tends to select and apply the strategy that produces the most beneficial combination of speed and accuracy for a given individual and for a particular sum. To make this selection, SCADS relies on a database comprising various kinds of data about strategies, including (a) global data – data about each strategy's efficiency aggregated over all problems (e.g., the speed and accuracy of a particular counting strategy on single-digit additions, such as 2+3, 4+1, or 6+7); (b) featural data – information about the efficiency of each strategy on problems with a particular feature (e.g., the speed and accuracy of that particular strategy on single-digit additions with both addends smaller than 5, such as 2+3 and 4+1); and (c) problem-specific data – data about each strategy's efficiency on particular problems (e.g., the speed and accuracy of that strategy on 2+3). In short, when SCADS is presented with a problem, it activates the global, featural, and problem-specific data about the speed and accuracy of each of the available strategies, which is decisive for the actual strategy choice being made.

Clearly, the flexibility concept underlying SCADS reflects a more complex and more sophisticated view on the strategy choice process, wherein affordances inherent in the item have to be seen in relation to and balanced with subject characteristics of the individual solving the task to be called flexible or adaptive. More specifically, SCADS views flexibility according to the individual's own experience with, knowledge about, and executive efficiency in the various strategies available in his or her strategy repertoire for performing a certain type of arithmetic tasks.

Conceptualizations of strategy choice that comprise both task and subject variables try to capture this assumed complexity of the strategy choice process in the research methodology. A method that acknowledges this more sophisticated view on strategy flexibility is the choice/no-choice method (Siegler & Lemaire, 1997; for a recent review of this method and the research it has initiated see Luwel, Torbeyns, Schillemans, Onghena, & Verschaffel, 2009). This method requires testing each subject under two types of conditions. In the choice condition, subjects can freely choose among the available strategies to solve each problem. In the no-choice conditions, they must use one particular strategy to solve all problems. The number of no-choice conditions equals the number of strategies available in the choice condition. The obligatory use of one particular strategy on all problems in the no-choice condition allows the researcher to obtain unbiased estimates of the speed and accuracy of the strategy. Comparison between the data about the accuracy and the speed of the different strategies as gathered in the no-choice conditions and the strategy choices made in the choice condition allows the researcher to assess the

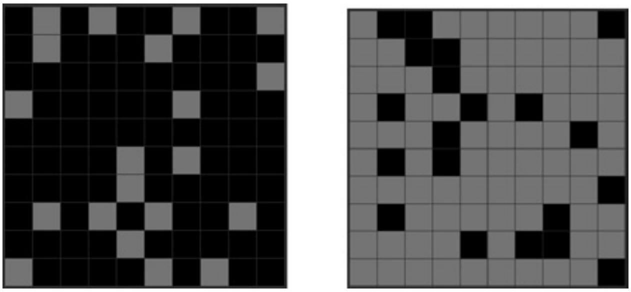

Fig. 10.1 Examples of a trial with 20 (*left*) and 80 (*right*) *colored blocks* in a 10 × 10 grid (Luwel, Verschaffel et al., 2003)

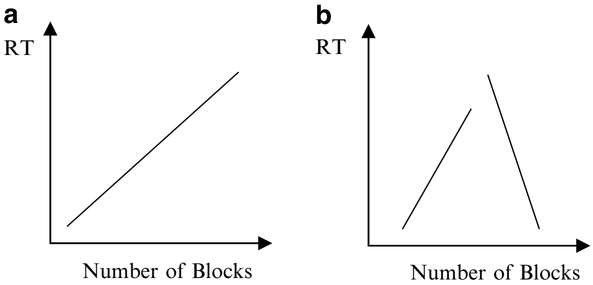

Fig. 10.2 Hypothetical response-time pattern for a subject who always applies the addition strategy (**a**) and one who uses the addition and subtraction strategy adaptively (**b**) (Luwel, Verschaffel et al., 2003)

flexibility of individual strategy choices in the choice condition in a scientifically appropriate way: Does the subject (in the choice condition) solve each problem by means of the strategy that yields the best performance – in terms of accuracy and speed – as evidenced by the information obtained in the no-choice conditions?

Luwel, Verschaffel, Onghena, and De Corte (2003) (see also Luwel, Lemaire, & Verschaffel, 2005) have applied the same choice/no-choice method to investigate the flexibility of people's strategy choices when judging numerosities presented in a rectangular grid (see Fig. 10.1).

Essentially, these authors claimed that there are two main types of strategies to solve this task: an *addition strategy*, wherein the total number of blocks in the grid is divided into subgroups and the number of blocks in each subgroup is added to a running total, and a *subtraction strategy*, in which the (subitized, counted, or estimated) number of empty squares is subtracted from the total number of squares in the grid. Moreover, they knew (from previous studies, see Verschaffel, De Corte, Lamote, & Dhert, 1998) that each strategy has a specific and clear pattern of response times as a function of the numerosity of blocks in the grid, as shown in Fig. 10.2.

Luwel, Verschaffel, et al. (2003) designed and applied the following measure of adaptivity of people's strategy choices for the given task. According to the

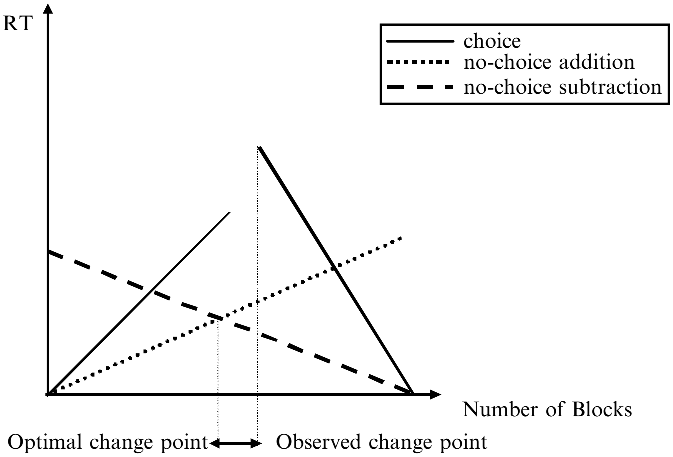

Fig. 10.3 Schematic presentation of the difference between the "observed" and the "actual" change point (Luwel, Verschaffel et al., 2003)

above-mentioned analysis, the adaptive application of the addition and subtraction strategy in the choice condition would yield a two-phase response-time pattern similar to the hypothetical pattern in Fig. 10.2b, exhibiting a linear increase in response times with an augmenting number of blocks followed by a linear decrease. By applying a two-phase segmented linear regression model on the individual response times in the choice condition, one can determine the *observed* change point. Besides this observed change point, an *optimal* change point can be derived based on the response-time patterns of the two no-choice conditions. This can be derived by running a simple linear regression model on the individual response-time patterns for the correct trials of both the no-choice addition and the no-choice subtraction condition. Each regression line represents an unbiased estimate of the speed of each of the strategies. In short, the intersection of both regression lines demarcates the optimal change point, that is, the trial on which the subtraction strategy becomes faster than the addition strategy, without a loss in accuracy. Since the optimal change point indicates the trial on which it is for a particular individual most efficient to switch from the addition strategy toward the subtraction strategy, we consider a subject who switches to the subtraction strategy on this trial (in the choice condition) as being perfectly adaptive. As a consequence, the absolute difference in location between the observed and the optimal change point can be conceived as an individual measure of adaptivity: the closer both types of change points are located to each other, the better an individual's strategy choices are calibrated to his or her "unbiased" estimates of strategy performance. In other words, the *smaller* the difference, the *more* adaptive the strategy choices of the subject (see Fig. 10.3).

Luwel, Verschaffel, et al. (2003) found for a group of young adults a relatively small mean absolute difference between the observed and actual change point of 4.05. Moreover, a significant correlation (.34) was found for the whole group of participants between participants' observed and actual change point. Both findings are indicative of the claim that these young adults did not merely rely on task features but also on subject-specific information about how quick and good they were at performing both types of strategies (on different types of problems) when deciding what strategy to use for a given item.

While the study by Luwel, Verschaffel, et al. (2003) confirms that task variables (such as the proportion of colored blocks in a grid) have a clear impact on people's strategy choices, it suggests at the same time that the flexibility of these strategy choices is better grasped by a model that *also* takes into account how good people are at performing the different strategies available in their strategy repertoire, as implemented in Siegler's SCADS model. Indeed, if participants would have chosen their strategies on the basis of task characteristics only, one would have expected that the actual change point would be more or less the same for all participants (i.e., being located on a numerosity somewhat larger than the mathematical midpoint, given the larger complexity of the subtraction strategy compared to the addition strategy, see Luwel, Verschaffel, et al., 2003). The data, however, revealed that participants exhibited a rather large variability in the location of their actual change points ($M=29.68$, $SD=4.60$, range: 25–42).

Recent theoretical developments in the field of learning and instruction, especially with the rise of situated-cognition or sociocultural views (Greeno, Collins, & Resnick, 1996), have indicated that the issue of strategy flexibility might be even more complicated than suggested by cognitive computer models such as Siegler's SCADS model. The problem with such models is that they ignore situational or contextual variables (besides task and subject variables) that could also bear an influence on people's strategy choice processes, except for a number of circumstantial conditions that can be fitted rather easily into these cognitive (computer) models and experimental designs, such as situational emphasis on speed versus accuracy (Siegler, 1996), demands on cognitive resources or working memory (Hecht, 2002), the base rate with which different types of problems are presented (Lemaire & Reder, 1999), or the characteristics of the item(s) immediately preceding the actual item (Siegler & Araya, 2005; Schillemans, Luwel, et al., in press). Examples of such complicating sociocultural variables are students' ways of making sense of the task, their attempts to meet the implicit expectations of the teacher or the researcher, and the broader sociocultural or educational context wherein they must select and execute an arithmetic strategy. In her review article, Ellis (1997) argues that with age and experience, children not only construct a mental database including information about strategy, speed, and accuracy but also develop (implicit) knowledge and beliefs regarding the sociocultural expectations and norms, which may also guide their strategy choices:

> Within Western cultures, and on school-like tasks, speed and accuracy are extremely salient features of performance. Clearly, however, accuracy and speed are not the only variables that influence strategy choice. Observations of problem solving in non-Western cultures and during joint problem solving suggest a host of other variables that might fruitfully be examined within a framework of strategy choice. Like concerns for speed and accuracy, these variables are predicted to influence strategy choice at an implicit level (p. 510).

In short, Ellis' point is that an individual may sometimes select and execute a particular mathematical strategy, not because that strategy has the greatest chances of yielding the best answer to a given problem in the shortest time but because of other factors (which are neglected in these cognitive models of strategy choice), such as the tendency to please or impress the teacher or a researcher, the pleasure of experiencing the aesthetic beauty of applying a particular strategy, or the eagerness to acquire mastery in an unfamiliar but more advanced strategy. Building further on Ellis' point, we argue that including considerations about the situation or context into one's strategy choice process might reflect a higher level of strategy adaptivity than when only task and subject features are taken into account. This consideration might also lead to better task performance, according to the criteria – more or less explicitly – defined by the situation. For example, children might demonstrate a "cognitively" suboptimal level of adaptivity (in terms of adaptivity to task and subject features), because they chose a strategy selection in line with the existing sociocultural norms and classroom practices (Torbeyns, Verschaffel, & Ghesquière, 2005).

As an example of a study that fits into this latter flexibility concept, we refer to Carr and Jessup (1997), who found gender-related differences in the arithmetic strategies used by first-grade children (boys started earlier to exchange counting strategies for retrieval strategies than girls) that could not be explained in terms of gender differences in the actual mastery of the various strategies. The differences were in the nature and the strength of the girls' and boys' beliefs about what type of strategies would be most valued (as indications of ability) by their teacher and their parents. More specifically, the boys decided more than girls to apply a strategy they mastered less well (i.e., fact retrieval) when they believed that the use of that strategy (rather than counting) would be appreciated by their parents and teacher.

An example at a more advanced level of how strategy choices are filtered by people's domain-related beliefs comes from our own research group, relates to solving word problems algebraically or arithmetically (Van Dooren, Verschaffel, & Onghena, 2002). To illustrate this type of filtering, two word problems follow according to a rational task analysis. In the first word problem, "I have 58 animals: twice as much rabbits as ducks, and 2 chickens less than rabbits. If you know that I have 22 chickens, how many of each other kind are there?" This problem can be easily solved arithmetically by "undoing" the arithmetic operations "hidden" in the problem ($22+2=24$ rabbits and $24 \div 2=12$ ducks). The same arithmetic approach, however, is not applicable to the second word problem, "I have 58 fruit trees in my garden. There are twice as many apple trees as pear trees and 2 prune trees less than apple trees. How many are there of each kind?" For this problem, the algebraic approach of setting up and solving an equation seems more appropriate (Solution: $x+2x+(2x-2)=58$; $x=12$; hence, 12 pear trees, 24 apple trees, and 22 prune trees). Van Dooren et al. (2002) investigated how different groups of preservice teachers (future elementary school teachers versus future lower secondary school mathematics teachers) solved such problems. They found that a considerable number of preservice elementary school teachers flexibly switched between arithmetical and algebraic strategies depending on the word problem that needed to be solved. Secondary school teachers, on the other hand, were more strongly inclined to solve all problems with the algebraic techniques, even those problems for which much simpler and quicker arithmetic methods existed. They referred to their future student audience (lower secondary school students) and expressed strong beliefs about the intrinsic value of algebraic thinking as formal and more widely applicable (in comparison to arithmetic solution methods), which had contributed to their decision to rely so heavily, and in many cases even exclusively, on the algebraic method, even on those problems for which an arithmetic method was irrefutably quicker and easier. This study shows that, when trying to understand flexibility of strategy choices, one needs to consider (people's interpretations of) contextual aspects as an additional factor.

Currently, researchers are trying to gain more insight into the role of sociocultural factors affecting people's strategy choices in mathematical tasks by using a variety of methods, such as (a) detailed analyses of video-taped mathematics lessons wherein children (learn to) make strategy choices, followed by video-based stimulated interviews (see e.g., Bisanz, 2003), and (b) systematic manipulation of the didactical or experimental contract (e.g., by presenting the same set of problems repeatedly and each time rewarding a different aspect of people's strategy behavior, such as the correctness, the speed, or the elegance of their solution process; see e.g., Greer, 1997).

In sum, although empirical evidence is still scarce and more convincing findings are absolutely necessary, researchers' view on strategy choices in mathematics education has recently been enriched by the sociocultural perspective. People's strategy choices in mathematical tasks are not only determined by task and subject variables but also by characteristics of the environment in which they must demonstrate their mathematical skills and make their strategy choices. The strategy choices include people's beliefs about what representational and computational tools are allowed and the aspects of their strategy behavior – speed, correctness, certitude, simplicity, efficiency, elegance, formality, or generality of the solution strategy – that will be (most) valued in the given situation.

The above analysis engendered the following definition of flexibility (or adaptiveness) in one's strategy choices: Flexible or adaptive strategy use means the selection and execution of the most appropriate solution strategy (from a variety of strategies available in one's strategy repertoire) on a given mathematical task, for a given individual, in a given context or situation (see also Payne, Bettman, & Johnson, 1993; Verschaffel et al., 2009). Whether a strategy choice is considered as flexible or adaptive will depend on the complex and subtle interplay of the three elements in the above definition. Before advancing to the next section, we would like to provide one important additional comment on this definition.

The above definition of strategy flexibility does not connote anything about the consciousness of the strategy choice process. That is, the above definition of strategy flexibility does not imply that adaptive strategy choices are (always) made deliberately or that the reasons for making these adaptive choices are always accessible to or can be articulated by the individual. Indeed, strategy choice can be based either on associative mechanisms (as in Siegler's (1998, 2000) SCADS model) or can be metacognitive (Hacker, 1998). The latter means that individuals (a) possess conscious and, thus, potentially reportable knowledge or beliefs about the different strategies available in their strategy repertoire, about the accuracy and speed with which they can execute these different strategies, and about when and possibly why a certain strategy is particularly efficient for a given set of problems or under particular contextual circumstances, and (b) utilize these pieces of metacognitive knowledge or beliefs to control their strategy choices. For example, Carr and Jessup (1997) and Luwel, Torbeyns, and Verschaffel (2003) have empirically shown that even young elementary school children have already some knowledge about the mathematical strategies they use, for example, knowledge about how, when, and why to apply certain strategies, all of which is correlated with their actual strategy performance. In this respect, the work of Star and colleagues (Star, 2005; Star & Seifert, 2006) is worth noting. Strategy flexibility was defined by these authors not only in terms of *the ability* to select the most appropriate strategy but also in terms of *knowledge* about these strategies and how, when, and why to use them (Star & Newton, 2009, p. 558). Accordingly, when assessing strategy flexibility, these scholars always use measures of both knowledge and ability. Furthermore, strategy flexibility might also involve the inclination or willingness to engage in flexible behavior, the feeling for situations wherein behaving flexibly is important and even crucial, and experiencing feelings of pride and joy after success in demonstrating strategy flexibility. In other words, similar to adaptive expertise (Hatano & Oura, 2003), strategy flexibility should not be conceived as a purely cognitive skill, but rather as a disposition, which also involves metastrategic knowledge and beliefs as well as inclinations, attitudes, and feelings (Perkins, 1995).

10.3 Strategy Flexibility as an Important and Distinctive Characteristic of Expertise

Based on a recent review of the literature, Star and Newton (2009) conclude that although strategy flexibility is presently widely considered as an important component of proficiency in school mathematics (see e.g., Kilpatrick, Swafford, & Findell, 2001; Verschaffel, Greer, & De Corte, 2007), research convincingly showing that experts exhibit this flexibility and how exactly this flexibility contributes to their expertise is remarkably scarce and rather inconsistent.

When we analyze the studies that are discussed in the review of Star and Newton (2009) by means of the definition of strategy flexibility that was provided at the end of the first part of this chapter,[2] the results are rather disappointing. These studies

[2]For example, Dowker's (1992) analysis of the role of flexibility in mathematicians' estimations, Cortés (2003) study of flexibility in high school mathematics teachers', engineers' and scientists' solutions of (systems of) algebraic equations, or Carry, Lewis, and Bernard's (1980) analysis of the flexibility in expert solvers of algebraic equations.

Table 10.1 Means and standard deviations of both types of change points and their absolute difference (Luwel et al., 2005)

Age group	Observed change point		Optimal change point		Absolute difference	
	M	SD	M	SD	M	SD
Grade 3	39.67	6.28	29.93	1.83	10.67	5.21
Grade 6	33.16	5.79	24.16	1.46	9.11	5.93
Adults	29.65	4.60	27.22	1.36	4.05	2.88

Note. The fact that mean of the absolute differences differs slightly from the difference between the means of both types of change points is due to the presence of some negative differences between both types of change points

only show that the better estimators or solvers of equations demonstrated a richer repertoire of strategies and they considered certain characteristics of the task to a greater extent when making strategy choices than the novices, without trying to incorporate in the analysis certain subject or context features. Hereafter, we present a recent series of studies that attempted – in quite different but complementary ways – to investigate the flexible nature of experts' strategy choices in a way that is more consistent with our definition of strategy flexibility.

In a follow-up study of the investigation by Luwel, Verschaffel, et al. (2003) that was reported above, Luwel et al. (2005) asked participants from three different age groups – 25 third-graders (8–9 years.), 20 sixth graders (11–12 years.), and 37 university students (21 years.) – to determine different numerosities of green blocks that were presented in a 7×7 grid as quickly and accurately as possible in three conditions. In the choice condition, they were allowed to choose freely between the addition and the subtraction strategy to determine all numerosities from 1 to 49. In the no-choice addition condition, participants were required to determine the same numerosities by means of the addition strategy, whereas in the no-choice subtraction condition participants were asked to determine these numerosities by using the subtraction strategy. All other aspects of the method and analysis were the same as in Luwel, Verschaffel, et al.'s (2003) study. The adaptivity of strategy choices was again analyzed by comparing the distance between the observed change point (in the choice condition) and the optimal change point (as derived from the combination of the reaction-time patterns for the correctly determined numerosities in the two no-choice conditions, see Fig. 10.3). The means and standard deviations of the actual and optimal change points, as well as the absolute difference between these change points are displayed in Table 10.1 for each age group separately.

The results revealed that the absolute distance between both change points was significantly smaller in adults than in sixth graders or in third graders, and the distance was marginally significantly smaller in sixth graders than in third graders. Hence, Luwel et al. (2005) were able to show that as students get older and get more expertise in the task (as evidenced by their increasing overall efficiency in task performance), they also become more adaptive in their choices for an addition or a subtraction strategy, taking into account both task and subject characteristics.

Similar results were found in numerosity judgments using intelligence as the independent variable (Luwel, Foustana, Papadatos, & Verschaffel, 2011). These authors found that more intelligent children did not only perform better on the numerosity judgment task, but their better performance was accompanied by greater adaptivity of their strategy choices. More precisely, participants were better at fine-tuning their strategy choices to how efficient they were at performing both strategies on particular items.

An example of another attempt to investigate the flexible nature of experts' strategy choices in the domain of mathematics comes from an exploratory study by Star and Newton (2009). Also starting from the question, "Do experts exhibit strategy flexibility," these scholars first administered a test including various tasks that provided opportunities for experts to demonstrate flexibility (e.g., a problem in the form $a(x+b)=c$ composed so that c is divisible by a, namely, $7(n+13)=42$). After the tests, semi-structured interviews were conducted to probe experts' thinking about their strategies for solving algebraic problems. Experts were asked to explain how they solved certain problems, why they chose the strategies, whether they knew of other ways to solve the problems, and which strategies they preferred.

Interestingly, during the interviews, the researchers also explicitly questioned the experts in school algebra (two mathematicians, two mathematics educators, two secondary mathematics teachers, and two engineers) about their views on strategy flexibility and where and how they had developed that flexibility. Generally, experts indicated a preference for strategies that they deemed to be *easiest* (from a task-based perspective). Typically, the easiest strategy was the one that was faster, quicker, and had fewer steps. However, the latter was not the only consideration for choosing a strategy; reducing effort was also important. The experts also referred to the *neatness* or *beauty* of a strategy in explaining their strategy choices. For example, one expert noted that to solve the above-mentioned problem, he felt it was best to use division by 7 as the first step because "That was evenly divisible. If it wasn't divisible it wouldn't get a nice, clean answer." In addition to selecting a strategy based on its perceived ease of execution or neatness, experts also considered the specific characteristics (e.g., structure and coefficients) of problems in selecting a strategy. They also relied on their familiarity with problem types and strategies when determining the best approach for solving a given problem. However, experts' rationales for their strategy choices suggested their strong tendency to prefer elegant, efficient strategies even when these strategies were not actually used for solving a given problem. When they noticed during the interview that they had solved a problem in a suboptimal way, they explained that the reason for the less efficient method was usually a result of not looking carefully at the particular structure or coefficients of a problem. Toward the end of the interview, the experts were introduced to the construct of flexibility and were asked to reflect on their flexibility. Not surprisingly, they uniformly believed that they were flexible. Furthermore, when considering if they were ever taught flexibility, their typical answer was "No, never!" Instead, these experts offered two explanations for how they developed strategy flexibility – both of which minimize the role of instruction in imparting flexibility to their students. First, some experts felt that their own flexibility had emerged as a natural consequence of exposure to seeing similar kinds of problems over and over again, combined with a desire to solve problems as quickly as possible. Another explanation by others was that their flexibility had only started to develop as a result of their own teaching. When describing how he developed flexibility, one participant suggested, "I tutor students mainly who struggle, so I have just learned that if they can't see it one way, often trying another way helps them see something they didn't see before." Although the experts appeared to value flexibility and felt that it was an integral part of performing mathematics – consistent with experts' views on how their own flexibility developed – there was quite some variation as to whether they felt it was a good idea to teach students to be flexible. One participant stated, "You can learn some tricks from your teachers, but eventually it all comes down to doing it yourself" (see the next section). In short, the data from Star and Newton's study suggest that experts exhibit strategy flexibility in the domain of linear equation solving, but also that they do not consistently select the most efficient method for solving a given equation (from the task-based conception of flexibility, we would like to emphasize). However, regardless of whether experts used the best method on a given problem, they showed an awareness and an appreciation of efficient and elegant problem solutions. These experts were capable of making subtle judgments about the most appropriate strategy for a given problem, based on factors including mental and rapid testing of strategies, familiarity with a given problem type, and their own goals in the given situation (e.g., whether correctness, speed, or elegance was most valuable).

In sum, even though research is only emerging, various attempts have been made to grasp the quintessence of experts' strategy flexibility in the curricular domain of mathematics, departing from a richer definition of flexibility than one that simply looks at task characteristics. A variety of quantitative and qualitative data-gathering and data-analyzing tools have been used. The findings from these emerging studies suggest that experts in mathematics are characterized not only by making flexible or adaptive strategy choices that actually consider various kinds of factors but also by accompanying metastrategic knowledge, beliefs, attitudes, and feelings.

10.4 When and How to Strive for Strategy Flexibility

In many current curriculum reform documents, such as the curriculum and evaluation standards for school mathematics of the National Council of Teachers of Mathematics in the US (1989, 2000), the Numeracy Strategy in the UK (Straker, 1999), the *Proeve van een Nationaal Programma voor het Reken/wiskundeonderwijs* in The Netherlands (Treffers, De Moor, & Feijs, 1990), the *Handbuch Produktiver Rechenübungen* in Germany (Wittmann & Müller, 1990), and the *Ontwikkelingsdoelen en Eindtermen* for the elementary education in Flanders (1998), a common plea exists to strive for strategy flexibility. The belief in the educational value of that endeavor is not merely based on the idea that it will contribute to learners' computational proficiency. More importantly, the belief that providing opportunities for learners to develop and use various and flexible strategies for doing mental arithmetic, estimation, etc., will also promote conceptual knowledge, metacognitive knowledge and skills, and valuable beliefs, attitudes and feelings that are also important aspects of a genuine mathematical disposition (Verschaffel et al., 2007). As such, the aim of strategy flexibility can be considered as a first stepping stone toward adaptive rather than routine expertise in mathematics as described by Hatano and Oura (2003). However, this basic belief in the value of strategy flexibility, as well as some accompanying presuppositions about *when* and *how* to strive for it, have not yet been subjected to much systematic and scrutinized theoretical reflection and empirical research. Hereafter, we review the different positions and the relevant research evidence concerning these two questions related to the enhancement of strategy flexibility in mathematics education.

When? First, the issue of the optimal moment for beginning to strive for adaptive expertise in mathematics education must be considered. Several authors (e.g., Geary, 2003; Milo & Ruijssenaars, 2002) argue that one better teaches, first and above all, for "routine expertise" and only afterward changes one's aims and pedagogy in the direction of "adaptive expertise." Applied to elementary arithmetic, this view is adopted by mathematics educators who argue that one has to teach and practice for procedural fluency in the use of one strategy first before one can start working at strategy variety and flexibility. Thus, in the initial stage of the teaching and learning process, one strategy for solving all problems of a given type should be imposed on all children. For example, the decomposition-to-ten strategy (e.g., $7+8=.$: $7+3=10$ and $10+5=15$; $16-9=.$: $16-6=10$ and $10-3=7$) can be taught in grade 1 to solve all additions and subtractions "with a bridge over ten," or the standard jump approach (e.g., $34-29=.$: $34-20=14$ and $14-9=14-4\ 5=5$) to solve all subtractions in the number domain 20–100 in grade 2, or the conventional method of first applying the distributive law in equations of the type $3(x+5)=12$ in the first year of secondary school. The rationale for this instructional approach is that – as the National Mathematics Advisory Panel (2008) has recently argued – "practice allows students to achieve automaticity of basic skills – the fast, accurate and effortless processing of content information – which frees up working memory for more complex aspects of problem solving" (p. 30). We consider strategy flexibility, as conceived in our definition, as one of these more complex aspects of problem solving. But others (cf., Baroody and Dowker 2003; Gravemeijer, 2004; Selter, 1998) conjecture that the development of adaptive expertise is not something that simply can happen after people have developed routine expertise, but that education for adaptive expertise should be already present from the very beginning of the learning process – an idea that is expressed in the following quote from Bransford (2001):

> You don't develop it in a 'capstone course' at the end of students' senior year. Instead the path toward adaptive expertise is probably different from the path toward routine expertise. Adaptive expertise involves habits of mind, attitudes, and ways of thinking and organizing one's knowledge that are different from routine expertise and that take time to develop. We don't mean to imply that 'you can't teach an old routine expert new tricks'. But it's probably harder to do this than to start people down an 'adaptive expertise' path to begin with – at least for most people. (p. 3)

Applied to elementary school mathematics, for example, the latter position would imply that one does not postpone pupils' confrontation with and exploration of a variety of strategies until they have developed full routine mastery in one particular strategy, but stimulate strategy variety and flexibility already from the very beginning of the teaching and learning process. This approach is adopted in many reform-based textbooks that are becoming used more and more in Western countries, such as Germany and the Netherlands (cf., Gravemeijer, 2004; Wittmann & Müller, 2004). Research documenting the feasibility and value of such early and explicit teaching for strategy variety and flexibility is, however, quite scarce. Hereafter, we first report some studies that have explicitly examined the development of flexibility among school-aged learners, which appear to show the success of instructional interventions that aim at improving students' strategy variety and flexibility. Afterward, we present some further reflections and considerations.

In the context of a large-scale evaluation study, Blöte et al. (2001) examined the impact of two instructional programs on second graders' strategy flexibility in the domain of mental addition and subtraction in the number domain 20–100. One program emphasized strategy variety and flexibility, whereas the other program was more traditional, focusing on good procedural mastery of a single standard procedure (i.e., paying attention only to strategy variation and flexibility toward the end of the program). Using a test that addressed both learners' actual strategy use and their knowledge of various strategies (see Star, 2005; Star & Seifert, 2006), Blöte et al. found that children in the first program showed more flexibility in their proclaimed and actual use of strategies, but actual strategy flexibility lagged seriously behind proclaimed flexibility in both groups. Interestingly, these researchers also found that – independent of instructional program – children using only one strategy for a prolonged length of time had more difficulty adopting new strategies afterward.

Star and Seifert (2006) investigated, in a more controlled experimental setting, the impact of an instructional treatment whereby secondary school students had to solve the same problem in two different ways on their flexibility for solving algebraic equations. Specifically, students in an experimental group were asked to solve previously completed problems in new and different ways (i.e., with a different ordering of problem solving steps), whereas students in a control group solved a series of distinct problems using the single traditional way without being asked to use an alternative strategy. The researchers found that while the groups performed similarly with regard to accuracy, students in the experimental group (a) became more flexible in their knowledge of equation-solving strategies than students who were not asked to provide re-solutions using an alternative strategy, and (b) were more likely to use multiple strategies and to come up with new strategies for solving equations.

The problem with the previous study, however, is that students had already good mastery of one particular strategy before they were confronted with another one and were stimulated to develop flexibility in using both. In a more recent study, Rittle-Johnson, Star, and Durkin (2009) provided a more direct solution to the problem for when the most appropriate time is to strive for strategy variety and flexibility by investigating the importance of prior strategy knowledge in "learning from comparison." Seventh- and eighth-grade students learned to solve equations by comparing different solution methods to the same problem or by studying the examples sequentially. Unlike the previous study from this research team, many students did not begin the study with equation-solving skills, and prior knowledge of algebraic methods was found to be an important predictor of learning. Students who did not attempt algebraic methods at pretest benefited most from studying examples sequentially rather than from immediately comparing solution methods, whereas students attempting algebraic methods already at pretest learned more from comparing solution methods. The researchers explained that for students who were completely unfamiliar with algebraic methods rather than informal methods, the immediate confrontation with (the comparison of) various solution methods might have been too overwhelming. Solving equations is a complex process, involving multiple rules and variants, and the processing load of learning the rules and variants simultaneously likely overwhelmed their working memory (cf., also Sweller, van Merrienboer, & Paas, 1998). In short, the researchers concluded that students need sufficient prior strategy knowledge in a domain before they benefit from comparing alternative solution methods, and by doing so, become flexible in the use of multiple strategies. The conclusion is well in line with the so-called expertise reversal effect, which states that the instructional approach that is most effective for novices in the domain may not be the most effective for more experienced learners (Rittle-Johnson et al., 2009).

Although the results of Rittle-Johnson et al. (2009) latest study seem to indicate that novices in a domain should learn and practice one solution method before comparing the method to a second method or to compare methods from the beginning, the broader research literature about cognitive flexibility suggests that such a practice may not be without its problems either, especially if one takes a broader (mathematic) educational scope. Several researchers have documented the rigidifying effects of years of diligent practice in routine expertise in a particular skill, and they have highlighted how intensive and long-lasting practice in one single strategy for solving a narrow range of problems can reduce problem-solving flexibility and hinder performance-solving novel problems afterward. According to Feltovich, Spiro, and Coulson (1997) "there are effects on cognition that come with such an extended practice that could lead to reduction in cognitive flexibility – to conditions of relative rigidity in thinking and acting (while, we have noted, affecting other, more desirable goals, such as in efficiency and speed)" (p. 126). Some of the potentially rigidifying effects discussed by these authors are viewing the world as too orderly and repeatable due to schematization or routinization (Spiro, 1980), the phenomenon of "functional fixedness" as observed and described by the Gestalt psychologist Karl Duncker (1945), and the so-called reductive bias, which denotes a tendency among people to treat and interpret complex circumstances and topics as simpler than they really are, leading to misconception as well as to error and to limitation in knowledge use due to inertness (Coulson, Feltovich, & Spiro, 1989). Thus, given the possible decrease in strategy flexibility that might accompany increased routine experience in a certain strategy or skill, striving too long and too exclusively for such routine expertise and postponing engendering strategy flexibility until the moment that this routine expertise has been well established seems too risky.

Given the scarcity and inconsistency of the research-based evidence and recommendation, comparative research is greatly needed to investigate distinct instructional approaches that differ with respect to the precise moment at which strategy flexibility is aimed at, and to assess comparisons of learning, retention, and transfer effects on a broad scale of cognitive, metacognitive, and affective variables related to strategy fluency and flexibility.

How? This brings us to the second question: How? can educators design and implement effective instruction aimed at adaptive expertise in mathematics? In some instructional approaches (e.g., textbooks) that explicitly aim for strategy variety and flexibility, learners are provided with different solution strategies that can be used to solve a given type of sums together with an overall metastrategy for identifying particular subtypes of sums and for applying *the* most efficient solution strategy for each subtype (*a priori* definitions by the textbook author or the teacher). For example, in the first year's pupils' book of a new Flemish textbook series, first graders are taught three different strategies for performing additions with sums between 10 and 20: (a) the retrieval strategy, (b) the tie strategy (i.e., solving near-tie sums 7 + 8 = . by means of the tie sum 7 + 7: 7 + 8 = 7 + 7 + 1 = 14 + 1 = 15), and (c) the decomposition-to-ten strategy. Subsequently, they are explicitly and systematically taught how to use each strategy adaptively. In particular, children are taught to link each of these three strategies (the retrieval, tie, and decomposition-to-ten strategy) to a particular subtype of sums over ten for which that strategy is considered (by the textbook authors and the teacher) most efficient, namely, (a) tie sums (e.g., 6 + 6 = .), (b) near ties (e.g., 6 + 7 = .), and (c) all other sums over ten (e.g., 6 + 8 = .), respectively. In other textbook series, such as the German textbook series *Das Zahlenbuch* (Wittmann & Müller, 2004), the goal of strategy flexibility is achieved in quite a different way. With respect to sums between 10 and 20, for example, first graders' first confrontation with these sums happens also by presenting to them a variety of solution methods and by stimulating them to understand these different methods. They subsequently select and develop their own preferential strategy or strategies, and talk about and reflect upon their selections under supervision of the teacher. Although flexibility is viewed as very important by the authors of *Das Zahlenbuch*, the book lacks explicit teaching toward the establishment of fixed and uniform associations between particular strategies and particular problems. At first sight, the approach followed in the Flemish series appears to go further in teaching children to be(come) flexible, because it embodies an instructional approach that provides more direct teaching of and more intensive practice in a clear metastrategy for solving each problem type with its most efficient strategy. However, based on the theoretical considerations provided in the first part of this chapter, providing children with such a (quasi-) algorithmic metarule for linking problem types to solution strategies and systematic training in the fluent application of that metarule is objectionable. This type of approach which refers rather to a notion of flexibility that merely looks at task variables (without any consideration of individual or contextual factors) will not yield strategy flexibility as we have conceived and defined it.

Such instruction misjudges the quintessence of strategy flexibility, which involves a *personal and insightful* choice based on weighing different kinds of affordances, not only task-related, but also subject- and context-related ones. The latter conception of strategy flexibility seems much better targeted in *Das Zahlenbuch*, in which children are stimulated to develop a strong personal framework of number relations and to use these relations as building blocks for flexible and adaptive mental computation.

The more one dismisses the notion of strategy flexibility that merely looks at task characteristics, and the more one tries to depart from a more sophisticated notion of strategy flexibility, the more one will agree that there is no easy shortcut to learning to become adaptive. Strategy flexibility is not a process that can be (quickly and easily) *trained* or *taught*, but something that must be (continuously and gradually) *promoted* or *cultivated* by creating a classroom practice and culture that supports the development of this rich concept and that acknowledges that adaptivity is a metacognitive and affective matter as well as a (purely) cognitive one (Hatano & Inagaki, 1992).

In the mathematics education literature, several suggestions have been made about how to work toward the insightful, flexible, and creative use of strategies as a first stepping stone toward adaptive rather than routine expertise (see e.g., Blöte et al., 2001; Star, Rittle-Johnson, Lynch, & Perova, 2009; Thompson, 1999). These recommendations show remarkable similarities with what is recommended in the general literature on how to stimulate adaptive expertise, such as Hatano and Oura's (2003) set of conditions for placing students on a trajectory towards adaptive expertise: (a) encountering novel problems continuously, (b) engaging in interactive dialogue, (c) being freed from urgent external need to perform, (d) being surrounded by a group that values understanding.

While these mathematics educators have already suggested inspiring sets of instructional materials and approaches for placing students on a trajectory toward strategy flexibility that is consistent with the above rich conception of the term and with the instructional design principles of Hatano and Oura (2003), the empirical evidence is still problematically scarce, as was recently emphasized in reports of national advisory panels of the state of affairs with respect to (elementary) school mathematics in the Netherlands (Koninklijke Nederlandse Akademie van Wetenschappen, 2009) and the US (National Mathematical Advisory Panel, 2008). Notwithstanding, studies are greatly needed that aim at assessing – for a broad range of learner outcomes (procedural, conceptual, metacognitive, and affective) – the effectiveness of instructional practices and cultures differing in terms of whether, when, and how they try to realize strategy flexibility.

10.5 Conclusion and Discussion

In this chapter, we have described and commented on how strategy flexibility or adaptivity has been defined, operationalized, and investigated from different theoretical perspectives on (elementary) mathematics learning and teaching, resulting in a working definition as the selection and execution of the most appropriate solution strategy (available in one's strategy repertoire) on a given mathematical task, for a given individual, in a given context or situation. Then, we reported empirical research indicating that strategy flexibility is a distinctive feature of being good at mathematics or having mathematical expertise. In the third and final part, we pleaded for educators to aim for strategy flexibility in (elementary) mathematics education as a first stepping stone toward adaptive expertise in this domain, and we reported available evidence from intervention studies.

This review has shown, however, the lack of clarity surrounding the issue of strategy flexibility, not only about how we can best conceptualize and differentiate the different kinds of factors related to the task, the subject, and the context that are taken into account by an adaptive expert, but also about how adaptive strategy choice behavior is related to people's metacognitive knowledge and beliefs. Although we have repeatedly exemplarily referred to this relationship throughout this chapter, a more systematic theoretical and empirical analysis is strongly needed of how the various components of mathematics-related beliefs (i.e., beliefs about mathematics as a discipline, e.g., whether one has a platonic or constructivist view on mathematics; beliefs about the learning of mathematics, e.g., whether one believes that there is only one correct way to solve a mathematical problem; and about the social context of mathematical activities in the classroom, e.g., what it means to be a good student in one's particular mathematics class) (De Corte, Mason, Depaepe, & Verschaffel, 2011) are related to the flexibility of learners' strategy choices. A valuable starting point for this research could be Muis' (2007) general model of the relations between epistemic beliefs and self-regulated learning and its application to mathematics problem solving and learning (Muis, 2008). According to this model, epistemic beliefs are part of the various internal conditions of the task environment, which influence the standards applied by students when defining problem-solving or learning goals. This, in turn, influences the cognitive strategies that are selected to deal with a task and the extent to which metacognitive processing is activated during task execution. The products are then compared to the set standards through metacognitive monitoring. For example, if students have the unproductive belief that informal solution methods (like counting) are detestable, they are less likely to seriously consider all possibly promising solution strategies and, thus, behave in the strategically most flexible way (according to our definition).

Another issue that deserves further research is the relationship of strategy flexibility in mathematics education (a) with other aspects of cognitive flexibility in mathematics problem solving and learning, such as flexibility in using different mathematical representations (see Acevedo Nistal, Clarebout, Elen, Van Dooren, & Verschaffel, 2009), but also (b) with how one's flexible use of strategies (and representations) is related to one's cognitive flexibility in other curricular domains and on measures of cognitive flexibility in general.

The scientific progress with respect to these conceptual and empirical issues is closely linked to the development of appropriate measures of strategy flexibility, which is another important issue for further research. Arguably, the more complex and multidimensional one's conception of strategy flexibility is, the more difficult to measure it in a reliable and valid way.

From a mathematics educational perspective, our review has also revealed that a great amount of discussion can be found about the value and feasibility of striving for strategy flexibility, especially for younger and weaker children. Only after intervention studies have shown convincingly and repeatedly that instruction that strives for insightful, flexible, and creative strategy use leads to the intended cognitive and dispositional outcomes without resulting in significant loss in routine mastery of certain valued procedures, will researchers be in a strong position to convince policy makers, designers of mathematics textbooks and assessments, and the broader public of the importance of striving for strategy flexibility as a first stepping stone toward adaptive expertise in mathematics education, from a young age on and for all children, rather than reserving it as a "pinnacle" for those who have first developed routine expertise.

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Chapter 11
Conclusion

Geraldine Clarebout, Rainer Bromme, Elmar Stahl, and Jan Elen

11.1 Introduction

This book addressed the notions of (epistemological) beliefs and cognitive flexibility throughout different chapters. Whereas some chapters focus mainly on epistemological aspects and others on flexibility, all chapters tried to make the connection between these two concepts.

While the different chapters address these concepts, it becomes clear that more consensus is reached in the definition and terminology of cognitive flexibility – although with a specific focus by Verschaffel et al. – than for epistemological beliefs.

The different chapters reveal and Briell et al. make it very explicit that there is an explicit need to distinguish between a conception and a process oriented form of personal epistemology. The importance of the distinction requires a different terminology, the use of a different set of instruments and results in different types of research questions.

Based on the review of Briell et al., it can be argued that the notion "epistemological beliefs" refers to a conception-oriented form of personal epistemology (statement 1 Briell et al.). Epistemological beliefs (or epistemic beliefs as Kienhaus and Bromme label them) are traditionally defined as beliefs about the nature of

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knowledge and knowing. One recurring issue in the research on epistemological beliefs remains unresolved. The discussion on whether beliefs about learning are part of epistemological beliefs continues. Schommer-Aikins does include beliefs about learning under the notion of epistemological beliefs. In her reasoning, epistemological beliefs refer to an encompassing system of beliefs. This, of course, raises the question on what beliefs may belong to the system. Given the overall consensus, we do suggest to use the notion of epistemological beliefs when referring to beliefs about knowledge and knowing.

A second element identified by Briell et al. is the process-oriented form of personal epistemology (statement 2 Briell et al.). A very clear example is the epistemological judgments as discussed by Stahl. This process-oriented form of personal epistemology includes activities of amateur epistemologists that mimic professional epistemologists (Briell et al.). While this might be the case, Kitchener clearly distinguishes between professional epistemology and personal epistemology.

With respect to defining cognitive flexibility, most authors refer to the definition of Spiro and colleagues (Spiro, Coulson, Feltovich, & Anderson, 1988; Spiro & Jehng, 1990; Spiro, Feltovich, Jacobson, & Coulson, 1991). Some authors extend this definition or highlight specific aspects. For instance, Schommer-Aikins assumes that cognitive flexibility includes adaptive changing and monitoring the efficacy of the change. Kienhaus and Bromme also include flexibly adjusting different possible explanations for experiencing uncertainties in scientific knowledge into the definition of cognitive flexibility.

Given the large consensus, further research can best build on the definition of cognitive flexibility as initially proposed by Spiro.

In this conclusion, we briefly review statements from the different chapters. It seems impossible at this stage to integrate these statements in a robust theoretical framework. It is possible, though, to specify a number of research lines that are relevant with respect to personal epistemology, cognitive flexibility, and the relation between these two concepts. The different statements also contain important messages with respect to measurement issues.

11.2 Personal Epistemology

When referring to stability as normality in educational psychology (statement 2 Stahl), Stahl directly addresses the importance of the context that is addressed. Epistemological judgments are not made in abstracto. Making epistemological judgments involves interactions among a diverse set of elements. Two of these elements are epistemological beliefs and contextual cues. The idea of epistemological judgments as complex and situated is closely related to the view of Hammer et al. who stress the notion of "epistemological resources." The idea is also supported by Schommer-Aikins when she favors the idea of an encompassing view on epistemological beliefs.

That personal epistemology is an important factor in everyday life is clearly revealed in the notion “epistemic validation” as proposed by Richter. In Richter’s view, epistemic validation pertains to the active and strategic validation of incoming text information against previously acquired knowledge and beliefs. Epistemic validation is assumed to rest on two types of cognitive processes: (automatic) epistemic monitoring and (strategic) epistemic elaboration (statement 2). For Kienhaus and Bromme, epistemic monitoring or the check for inconsistencies and plausibility of information is an important aspect of cognitive flexibility. Epistemic monitoring requires little cognitive effort and results in a decision on the validity of information. Epistemic elaboration, on the other hand, is resource demanding, and will only be possible when sufficient cognitive resources are available. Because epistemic elaboration helps learners to construct a rich situational model, we may assume that epistemic elaboration strongly supports learning. Unfortunately, empirical evidence about this relationship is still sparse. In Richter’s view, epistemic elaboration is affected by learner’s epistemological beliefs, which are conceived as some kind of metacognitive knowledge.

While Richter’s model helps to consolidate existing research evidence and to identify relevant research questions, it is also clear that the model can be gradually elaborated in order to better understand the actual processes involved in epistemic processes. Furthermore, there is a need to identify other everyday situations such as argumentation in which personal epistemology does play a role and to investigate whether the model is also applicable for those situations.

Different chapters identify different dimensions of epistemological beliefs: certainty, simplicity, source, and justification of knowledge. There seems to be no agreement on the existence nor on the relevance of identifying such dimensions (see for instance the inclusion of beliefs on learning by Schommer-Aikins). Stahl raises the issue whether it is needed to always retrieve these dimensions in factor analyses and whether we should look at the interaction between different cognitive elements. Despite these remarks, Roex et al. tried to more directly investigate whether these dimensions can be found in medical trainees. Evidence was only found for justification of knowledge. A strong suspicion is raised that this is caused by the students’ evidence-based medicine program that stresses justification. In other words, these authors argue that instruction may affect the strength of particular dimensions of epistemological beliefs.

11.3 Cognitive Flexibility

A first group of statements on cognitive flexibility can be found in Chap. 3 (statements 1 and 2 Stahl). In a first statement, Stahl refers to the anatomy of the eye to indicate that while cognitive flexibility is normal rather than an exceptional case, in educational psychology, stability rather than flexibility is the starting point. In other words, Stahl raises fundamental questions on the current approach to study cognitive flexibility.

While most chapters deal with cognitive flexibility in adults, or learners who are supposedly cognitively flexible, a developmental view is offered by Sodian and Barchfeld. Starting from the idea that cognitive flexibility enables us to think of alternatives, to take perspective, these authors show that cognitive flexibility might already be present in infants of 9 months old. This supports the view of Stahl on the “normal” character of cognitive flexibility.

Cognitive flexibility – be it in a specific meaning – gets most directly addressed by Verschaffel et al. Strategy flexibility in mathematical problem solving entails the efficient adaptation of one’s strategies to task, subject, and context variables. According to Verschaffel et al., three elements are needed to define strategy flexibility (statement 1), namely, the task, the individual, and the context. While one could wonder whether including these three concepts into the definition of flexibility, does not make every person flexible, the authors indicate that strategy flexibility should be aimed at from the start of the teaching/learning process (statement 3). It is interesting to note that while the authors themselves doubt about the feasibility, Sodian and Barchfeld indicate that instruction on flexibility is effective, even for 6 years old. It seems that even young children can learn to become cognitively flexible and to generate an alternative theory. It remains unclear whether instruction for cognitive flexibility can be effective and if it is so, how that instruction should look like.

The different chapters seem all to agree on the importance of cognitive flexibility. Further conceptual and empirical work is clearly needed to identify in what circumstances and for what interpretation of cognitive flexibility, it is exceptional rather than normal. The different chapters also include a call for more intervention research to help design environments that stimulate the development of cognitive flexibility as a domain-general and a domain-specific disposition.

11.4 Relation Between Personal Epistemology and Cognitive Flexibility

A major focus of this book was the exploration of linkages between different research traditions and theoretical frameworks. A number of advances were made.

Schommer-Aikins focuses in her contribution on learners who spontaneously are cognitively flexible. She conceives cognitive flexibility as a predisposition. Epistemological beliefs and cognitive flexibility are directly linked in argumentation. For Schommer-Aikins, epistemological beliefs predict learners’ argumentation performance, while cognitive flexibility is related to willingness to argue and tolerance for disagreement. Mature epistemological beliefs will increase the willingness to argue. In her view, epistemological beliefs represent a metacognitive standard of what it means to learn or to know. The metacognitive nature of epistemological beliefs makes them play an important role in monitoring and self-regulation processes.

For Kienhaus and Bromme, cognitive flexibility clearly manifests itself in finding an adequate explanation for experienced inconsistencies. Being able to deal with such inconsistencies requires a realistic view of both one's own competencies (beliefs about ability – statement 1) and the boundaries of scientific knowledge (epistemic beliefs – statement 2). This means that for Kienhaus and Bromme, epistemic beliefs influence the way people deal with information (e.g., on the Internet). They also indicate that dealing with different kinds of information may evoke qualitatively different beliefs or different facets of epistemological beliefs. In a similar vein, Richter defines cognitive flexibility in relation to dealing with conflicting information and defines it as the ability to develop a justified point of view. According to him, the extent to which readers engage in epistemic elaboration will determine the extent to which they show to be cognitively flexible. In order to define when learners reach cognitive flexibility when learning from multiple texts, the mode of dealing with conflicting information can be looked at, namely, assimilative or elaborative. In an assimilative mode, the prevailing situational model will be used, and this seems to be inflexible. In an elaborative mode, the learner will engage in elaborative monitoring.

While it is a general expectation that sophisticated beliefs lead to higher levels of cognitive flexibility (statement 2: Roex et al.), no clear confirmation could be found for this expectation. Interestingly, a moderate level of sophistication was significantly correlated with cognitive flexibility. This seems to suggest that the relation between epistemological beliefs and cognitive flexibility might be nonlinear and that highly sophisticated beliefs may inhibit cognitive flexibility. This thought was also made by Schommer-Aikins (Chap. 4). A linear relation may result in a lack of consistency in learning and problem solving.

11.5 Measurement Issues

As indicated in a number of chapters, certainly with respect to epistemological beliefs, measurements issues have been raised in previous research and again in the current chapters. Briell et al. stress the importance of using more than one instrument to make inferences about learner's epistemological beliefs. This may resolve the issue of whether empirical differences may be instrument related or not. In the study of Roex et al., a composite measurement was used. A high score on all aspects of the composite measure was assumed to reveal high cognitive flexibility. Briell et al. as well as Stahl encourage the elaboration and use of new research methods. Given the interactions between different cognitive elements (statement 3 Stahl), the importance is stressed for instruments that allow for fine-grained analyses and instruments that allow to collect process data.

In this respect, Kienhaus and Bromme suggest to use the Internet. They show that process data can be gathered when people encounter conflicting information on the Internet. They were able to investigate whether people in such circumstances refer to ability or epistemic explanations.

With respect to cognitive flexibility, one could argue that the perspective taking approach of Sodian and Barchfeld can be used as a promising measurement.

11.6 Overall Conclusion

Kitchener discusses in his chapter different pitfalls (statement 2) for personal epistemology researchers. Whether one agrees or not, a clear message is given that conceptual clarity is needed, as well as that a researcher should make a clear distinction between a philosophical theory of knowledge and a scientific theory of knowledge. Although overlapping questions are raised in philosophical epistemology and personal epistemology research, philosophical epistemology does not strive for empirical knowledge.

While some discussion still prevail with respect to the definition of epistemological beliefs and cognitive flexibility, it is also clear that we have reached a point of basic consensus.

With respect to the relation between epistemological beliefs and cognitive flexibility, various claims are made. In order to reach some conclusions, it seems that first reliable, valid research instruments will have to be elaborated. Once these reliable and valid research instruments have been found, assumptions on importance of epistemological beliefs for everyday situations can be more easily tested. Of clear interest will be the role of epistemological beliefs for learning. It will then also become more easy to investigate in full depth the challenging question of the precise nature of the link between (epistemological) beliefs and cognitive flexibility.

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