Learning from texts : extending and revising knowledge

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C H A P T E R

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Summary and Discussion

Summary

The aim of the current dissertation is to gain insight into the processes that are involved in learning from (multiple) texts in adults and children. The dissertation consists of five chapters. The first chapter introduces the topic of 'learning from texts' and provides an overview of the chapters that form the body of this dissertation. Two types of learning are differentiated: 1) learning as *extending* knowledge and 2) learning as *revising* existing knowledge. The second chapter includes a literature review in which relevant theories and current knowledge about learning from texts are summarized. This chapter identifies important knowledge gaps. In an attempt to begin to close the knowledge gaps Chapters 3, 4 and 5 describe studies that focus on relating multiple texts and revising knowledge. Specifically, in Chapter 3 a new research paradigm is introduced that can be used to study the process of integration across multiple texts. In Chapter 4 this research paradigm is used to study integration processes across texts in children. Chapter 5 describes a study that focuses on refutation texts. In this study the transfer of revised knowledge across texts is investigated. The remainder of the current chapter provides a more elaborate summary of Chapters 2 till 5, reflections and suggestions for future research.

Chapter 2: Literature Review

In Chapter 2 the literature on reading comprehension and memory is synthesized and reviewed to provide an overview of current knowledge about learning from texts. Because of overlap in the way comprehension and learning are defined in existing literature, a definition of each process was provided. Comprehension was defined as the process of building a (temporary) mental representation of the text that can be used to understand later parts of the texts or to answer questions about the text directly after reading. Learning was defined as the process of constructing a relatively permanent knowledge representation that can be used in a variety of situations in the (near and far) future (i.e. a representation that is decontextualized). Several factors were suggested that may contribute to the transition from a text representation to a knowledge representation. We argued that most of the suggested factors influence learning either by affecting the consolidation of information (for example, by repeatedly processing information) or by enriching information (for example, by processing information in different contexts). The main conclusions from the literature review are derived from synthesizing findings from several studies and models, but empirical evidence testing these conclusions has yet to be provided. The review targets important knowledge gaps in the existing literature and provides a basis for theoretically grounded hypotheses that can be empirically tested in the future. The studies reported in Chapters 3 to 5 demonstrate first attempts to close the knowledge gaps.

Chapter 3 and 4: Expanding Knowledge By Reading Texts

Adults (Chapter 3). In the two studies reported in Chapter 3, we created a new research paradigm that was used to investigate one aspect of integration across multiple texts: The activation of previous text information during reading subsequent texts. The multiple-text integration paradigm provides an implicit measure of spontaneous activation of information from previous texts. In this paradigm, information is presented in text pairs of which the second text contains an inconsistency. In one condition this inconsistency can be resolved by applying information from the first text (i.e. the explanation), but in the other condition this inconsistency remains unresolved. Differences in processing time of the inconsistent target sentence can demonstrate whether the explanation from previous texts was active during reading.

The results of Experiment 1 and 2 show that the inconsistency in the second text is processed faster when the first text provides an explanation for the inconsistency in the second text, compared to when the first text lacks an explanation for the inconsistency in the second text. This demonstrates that the information from the first text is spontaneously activated during reading the second text. To determine whether the reading time difference reflects a slow-down or speed-up, the conditions with and without explanations were compared to a consistent control condition in Experiment 1. The reading times in the condition without explanations slowed down relative to the control condition, whereas the reading times in the condition with explanations did not slow down relative to the control condition. This may be explained by a backward parallel search process, which should take less time when explanations are readily available, as is the case in the condition with explanations.

The reading time results in studies 1 and 2 support the hypothesis that information from previous texts is spontaneously activated during reading subsequent texts. This is in line with the description of passive reading processes in several models (Albrecht & O'Brien, 1993; Kintsch, 1998; van den Broek, Risden, et al., 1996). These models assume that information activates associated information in memory when there is sufficient featural overlap. The results suggest that there was sufficient overlap between the texts, thereby enabling the activation of prior text information. However it cannot be determined whether prior text information was still active or whether prior text information was reactivated because we did not collect data about the activation of prior text information before reading the target sentence.

In addition to measuring the reading times, the second study in Chapter 3 was extended by adding a measure of the mental representation (free recall). Free recall was included to analyze knowledge presentations. The expectation was that reading processes affect the construction of knowledge representations.

Therefore, the effect of the conditions with and without explanations on reading times should also be reflected in the knowledge representations. There was no consistent condition in Experiment 2, but the other conditions (with and without explanations) were the same as in Experiment 1. The representations were analyzed on several aspects, but none differed between the conditions with and without explanations. Apparently, the differences in reading times did not result in differences in the mental representation, at least not on the aspects that were analyzed. This is counter to what was expected based on the Landscape Model (van den Broek, Risden, et al., 1996), which assumes that processing patterns correspond with the resulting memory representations. This lack of an effect is possibly due to limitations in the measures that were used to assess the mental representation.

Children (Chapter 4). In this chapter children's' ability to integrate information across texts during reading was investigated. We used the same multiple-text integration paradigm as in Chapter 3 and tested a sample of children from Grade 4 and 6. Reading times of the inconsistent target sentences were compared between the condition in which the preceding text provided an explanation and the condition in which the preceding text did not provide an explanation. The results replicated those found for adults: Children read target sentences faster when they were preceded by texts containing explanations than when they were preceded by texts that lack explanations. This effect was found for both 4th and 6th graders. This shows that children also spontaneously activate information from previous texts during reading subsequent texts.

Free recall was also analyzed to determine whether the knowledge representation differed between the conditions with respect to connections across texts (i.e. intertextual integration). Children in both grades demonstrated more integration across texts in the condition with explanations compared to the condition without explanations. This is in line with what was expected based on the hypothesized correspondence between processing information and remembering information (van den Broek, Risden, et al., 1996): The reading time results suggest that information from both texts is concurrently activated, which may have led to integration in memory (Goldman & Varma, 1995; Kendeou & O'Brien, 2014; McRae & Jones, 2013; van den Broek, Risden, et al., 1996). This result differs from what was found for adults. This discrepancy may be the result of using different criteria to code integration in the recall reports in each study. Because the results in the child study are consistent with common theories, it is conceivable that the criteria that were used in the child study were more appropriate.

Individual differences in reading comprehension ability and working memory were also inspected. Reading comprehension is necessary for integrating

information across texts: If two individual texts are not comprehended, they cannot be meaningfully integrated. However, reading comprehension ability did not interact with the manipulations on both the reading time and recall measures, suggesting that it was unrelated to the ability to integrate information across texts during reading. This is surprising as comprehension involves the ability to integrate information *within* texts, and logically, this should be related to the ability to integrate information *across* texts. Both processes involve (re) activation of previous text information, comparison of previous text information to incoming information and integration of previous and incoming information in memory. The lack of an effect could be explained by ceiling effects: If the texts are easy to comprehend, then readers do not need advanced comprehension skills that could otherwise facilitate integration.

With regard to working memory ability it was expected that it would positively affect the ability to integrate information across texts. Working memory is a cognitive function that allows one to temporary store and process information in memory (for a review, see Cowan, 2014). It was argued that more advanced working memory skills enable readers to connect more information at the same time, across larger distances, which may result in more complex and elaborate knowledge representations of the texts (Just & Carpenter, 1992). However, working memory did not significantly interact with the conditions on both the reading time and recall measures, suggesting that it was unrelated to the ability to integrate information across texts. Similar to the reading comprehension result, the lack of an effect of working memory may reflect a ceiling effect. If task demands are low, then even readers with poor working memory may be able to integrate information across texts. This would explain the discrepancy between the results in the current dissertation and previous studies that did find a relation between working memory and the ability to integrate information within texts and learning (Cain et al., 2004; Daneman & Carpenter, 1980, 1983; García-Madruga, Vila, Gómez-Veiga, Duque, & Elosúa, 2014).

It can be expected that reading comprehension ability and working memory do affect integration across texts in challenging multiple text situations. Both sets of skills develop gradually as children move up the grades (Kendeou et al., 2009; Oakhill & Cain, 2012), and children who develop these skills sooner may be able to handle more complex integration situations than children that develop these skills later. The combined results in the studies in Chapter 3 and 4 show that the multiple-text integration paradigm is sensitive to differences in activation of prior text information. The paradigm could be used in future studies to determine under what circumstances readers activate information from previous texts when the situation becomes challenging, for example, when the distance between the texts is larger. This is especially relevant for children, who

often struggle with complex cognitive tasks because they are in the process of developing skills that are required for these tasks (Chapter 2).

Chapter 5: Revising Knowledge By Reading Texts

Another form of learning is targeted in Chapter 5: Revising misconceptions by reading texts. In Chapter 5 two studies are described that examine whether students with misconceptions learn from refutation texts and if so, whether their revised knowledge can be applied during reading a new text. A sample of undergraduate students in which certain misconceptions were common was selected. In Experiment 1, participants read refutation texts, transfer texts and non-refutation texts. Transfer texts were always preceded by refutation texts. The refutation and transfer texts had different story contexts, but the transfer text required activation of the same belief that was refuted and explained in the refutation text. The non-refutation text served as a control and required activation of a different belief. Each text contained a target sentence that required activation of the correct belief. Previous studies have shown that information that is inconsistent with prior beliefs is processed slower than information that is consistent with prior beliefs (e.g. Albrecht & O'Brien, 1993). Therefore, our expectation was that correct information is processed slower by readers with incorrect beliefs than by readers with revised (correct) beliefs. The first hypothesis concerned replication of previous working showing that refutation texts are more effective in revising incorrect prior beliefs than non-refutation texts. This should be reflected by faster reading times for a target sentence that requires activation of the correct belief in the refutation condition compared to the non-refutation. The second hypothesis and of main interest of this study concerned transfer of revised knowledge from refutation texts to new contexts. If readers transfer the revised knowledge to a different context (i.e. the transfer text), then a target sentence that is consistent with the correct belief in the transfer text should also be read faster than a target sentence in a non-refutation text. The results of Experiment 1 supported our hypotheses.

Experiment 2 was conducted to answer two remaining questions. First, is the observed transfer effect in Experiment 1 going to disappear when transfer texts are preceded by non-refutation texts that target the same beliefs? Second, could the effects of conditions be alternatively explained by differences between the target sentences across conditions? Experiment 2 was designed to address these two questions. In Experiment 2, participants read non-refutation texts, transfer texts, and refutation texts. The transfer text followed directly after the non-refutation text and involved the same belief, but each text described different story settings. The refutation text required activation of a different belief and was included as a control. Again, the first hypothesis was that the reading time

of the target sentence is slower in the non-refutation condition compared to the refutation condition. The second hypothesis was that reading a non-refutation does not lead to knowledge revision and transfer of revised knowledge. Thus, reading times of target sentences in transfer texts should be slower than those in refutation texts. By using the non-refutation version of beliefs that were targeted in refutation versions in Experiment 1 it could be determined whether the effects in Experiment 1 were due to conditions or due to differences between the target sentences. Because we expected the effects found in Experiment 1 to be due to conditions, we expected the transfer effect to disappear. More specifically, our hypothesis was that the target sentence in the transfer condition is read slower than the target sentence in the refutation condition. The results confirmed our hypotheses and are in line with the conclusions that were drawn in Experiment 1: Refutation texts facilitate transfer of revised knowledge to a bigger extent than non-refutation texts.

In Experiment 1 and 2 a transfer problem test was also administered. The purpose of this test was to obtain converging evidence for the effect of transfer from refutation texts to different situations. In this transfer problem test, students answered questions that required transfer of the revised knowledge. In both studies, students scored significantly higher when they read refutation texts compared to when they read non-refutation texts. So again, refutation texts were more effective in accomplishing transfer of revised knowledge than non-refutation texts.

The results of the two studies are in line with the Knowledge Revision Components (KReC) framework. This framework distinguishes five principles that are central to the knowledge revision process: 1) encoding, 2) passive activation, 3) co-activation, 4) integration, and 5) competing activation (Kendeou & O'Brien, 2014). In the KReC framework, it is assumed that once a misconception is encoded in memory it cannot be erased from memory (principle 1). As a result, it can be passively activated in the future (principle 2), for example, when a text is encountered that relates to the misconception. Knowledge revision will occur only when: The misconception is concurrently processed with the correct information (principle 3), the integrated representation that includes the misconception and the correct information is encoded in memory (principle 4), and the correct information is more dominant than the misconception in the integrated memory representation (principle 5). In the studies in Chapter 5, the refutation text facilitated concurrent activation of the misconception and the correct information by explicitly stating the correct and incorrect information in close proximity in the text (in line with principle 3). Consequently, co-activation may have led to integration of the misconception and correct information in memory. In addition, explanations may have facilitated the construction of

rich, interconnected representations (Kendeou et al., 2014), which may have facilitated the dominance of the revised knowledge in memory. The richness and interconnectedness of the representation may also explain why the revised knowledge was maintained at the transfer text and at the post-test (in line with principle 4 and 5).

The combined results of both studies and both measures demonstrate that refutation texts can facilitate transfer of revised knowledge to new situations. The question that remains is whether knowledge that is revised through refutation texts also transfers to different situations than those that were investigated in Chapter 5. There is no evidence that reading a single refutation text with explanation allows readers to transfer the revised knowledge to different physical, temporal, functional, and social contexts (Barnett & Ceci, 2002). However, as long as knowledge revision concerns knowledge that can be represented as a single idea unit (such as in the current study), the prediction based on the KReC framework is that the effect should transfer to different situations as well.

Discussion and Future Research

The chapters of this dissertation advance our understanding of several aspects of learning from texts by investigating different types of learning (knowledge extension and knowledge revision), by including several measures of learning (the learning process and the resulting knowledge representation), and by considering individual and developmental differences.

Learning From Texts: Processes

When comparing the process of extending prior knowledge from multiple texts and the process of revising prior knowledge by reading texts, some interesting similarities emerge. Both processes have been hypothesized to involve a) activation of prior information, b) co-activation of information, and c) integration of information. In the case of extending knowledge from multiple texts, this concerns activation of information from previous texts, as well as co-activation and integration of information across texts. In the case of revising knowledge, the processes involve activation of information from memory, as well as co-activation and integration of correct information from the text and misconceptions (Kendeou & O'Brien, 2014). These three processes are central in many models of reading comprehension (Goldman & Varma, 1995; Kintsch, 1988; van den Broek, Risden, et al., 1996) and memory (McRae & Jones, 2013). The results of the empirical studies are consistent with these models and extend existing models by showing that processes that operate during single text comprehension also apply to multiple text situations. In all experiments,

information from previous texts (with explanations in Chapter 3 and 4, and with refutations in Chapter 5) was (re)activated during reading subsequent texts. This is in line with models describing multiple text comprehension (Britt et al., 1999; Britt et al., 2013; C. A. Perfetti et al., 1999).

From the studies in this dissertation one may conclude that multiple text processes are not different from single text processes. But although readers may indeed require the same toolbox of reading strategies when reading single and multiple texts, there are several reasons why readers might process single and multiple texts differently. First, readers may have different expectations when reading single or multiple texts (Stadtler et al., 2013). In single texts, authors are expected to make relations explicit. As a consequence, readers may not attempt to infer relations themselves. In multiple texts, readers may be aware that most relations across texts are not explicit, because the texts can be written by different authors. This may stimulate readers to actively construct these relations. Second, multiple texts allow more dynamic processing. For example, readers can choose which text to process first, whereas the order in which information in single texts is presented is more fixed (although readers of course could process paragraphs in single texts in orders different than those determined by the author). Third, reading multiple texts is usually more challenging than reading single texts (for example, because the texts can be inconsistent), and as a result, readers may need to be more skilled at using certain reading strategies and they need to use reading strategies more frequently. These are just three examples, but there may be more reasons why the same information is processed differently in single texts compared to multiple texts.

This dissertation advances our knowledge about passive and spontaneous processes involved in learning from texts, but it does not address strategic reading processes. The texts that were used in the studies of this dissertation were relatively short, did not include source information, did not describe complex topics and were presented shortly after another. Therefore, strategic reading processes may not have been necessary. However, complex learning situations such as those encountered in schools often do require a strategic approach (Anmarkrud, Bråten, & Strømsø, 2013; Britt & Sommer, 2004; Cerdán & Vidal-Abarca, 2008; Hagen, Braasch, & Bråten, 2014; Wolfe & Goldman, 2005). Future studies should focus on the interplay between passive and strategic processes to determine how they affect processing of complex textual materials, such as those that are used in schools (van den Broek, 2010)

Methods for Investigating Learning Processes

Intertextual integration. In this dissertation a new method to study intertextual integration was introduced; the multiple-text integration paradigm (Chapter 3 and 4). Previously, the process of reading multiple texts was studied mainly by using think-alouds (Anmarkrud et al., 2013; Wolfe & Goldman, 2005), strategy reports (Bråten & Strømsø, 2011), and software that allows monitoring of reading behavior (Vidal-Abarca & Martínez, 2002). Many of these measures reflect strategic approaches and conscious decisions. However, *passive* reading processes have been argued to be the default reading mode when processing texts when there is no need to use strategic reading processes (Albrecht & O'Brien, 1993; McKoon & Ratcliff, 1992; van den Broek, Risden, et al., 1996) and readers are not always aware of those processes. The multiple-text integration paradigm has proven effective to study passive reading processes of which readers are not always aware. Now that the usefulness of the paradigm is established in a relatively artificial setting in this dissertation, important follow-up research should use this paradigm with more ecologically valid multiple texts. This may be informative for schools and educators.

It is important to note that the multiple-text integration paradigm can only be used to determine whether information from prior texts was *active* during reading. Whether other processes such as inconsistency detection, inconsistency resolution, etc. operated during reading the target sentence cannot be determined. In order to gain insight into these processes other measures may be more appropriate, such as think-aloud methods or eye-tracking. Obviously, there is not 'one' superior method, so the recommended approach is always to use several methods to investigate different aspects and to provide converging evidence for proposed hypotheses (B. W. Miller, 2015).

Knowledge revision. In this dissertation a new method to study transfer of revised knowledge was introduced (Chapter 5). Traditionally, transfer is assessed by asking students to report their solution to a novel problem (Alonso-Tapia, 2002). This requires students to retrieve the previously acquired knowledge and to verbalize their response. A potential risk with this method is that some students have the required knowledge but somehow are not able to verbalize a response. The advantage of the method in the current dissertation is that students do not have to consciously retrieve the knowledge, nor do they have to verbalize their answer, they just have to read a text and from their reading times it can be inferred whether they have spontaneously activated prior knowledge, thereby showing transfer.

In the transfer research domain there has been considerable discussion about what classifies as near and far transfer (Barnett & Ceci, 2002). When evaluating the 'distance' between the learning task (in the current dissertation; reading the refutation text) and the transfer task (in the current dissertation; reading the transfer text) with respect to the taxonomy of far transfer (Barnett & Ceci, 2002), the transfer task in this dissertation would probably be classified as 'near' transfer, because several aspects of the learning and transfer context were the same (time, surroundings, task, etc.). However, certain aspects could be easily modified in future research using the same research paradigm. For example, the transfer text could be presented at a later moment in time: Days, weeks or months later. The transfer text could also be presented in a different physical context, for example at home instead of at the laboratory.

It is important to keep in mind that reading times were used, and therefore the only thing that we can relatively safely conclude is whether information was active or not. An important component of the transfer process that is not exposed with our method is whether the activated information was used to comprehend the situation. It is possible that revised knowledge was merely activated because it was cued by the transfer text, but that readers did not understand how it was relevant to the transfer situation. Again, different measures such as think-aloud and eye-tracking should be used to answer questions related to resolution processes.

Learning From Texts: Knowledge Representations

Knowledge representations are the result of learning processes. In the literature review in Chapter 2 (ideal) knowledge representations are characterized as relatively permanent and decontextualized (i.e. being applicable to new situations), which differentiates them from text representations. It was concluded that the transition from text to knowledge representations is facilitated by consolidation and enrichment processes. Consolidation and enrichment can be accomplished by repeatedly and deeply processing the information in a variety of contexts. These and other insights from Chapter 2 were obtained by generalizing empirical findings and theories from related research fields (e.g. reading comprehension, memory) to the topic 'learning from texts'. In the studies in this dissertation, we did modest attempts to take permanency and decontextualization of the knowledge representation into account. To assess the permanency of the knowledge representation, we used free recall and questions in Chapter 3, 4 and 5. These measures revealed that information from texts is retained shortly after processing the information. However, to get a more accurate reflection of the permanency of the information in memory measures should be administered at least one day later, but preferably weeks or months later. To assess decontextualization of the knowledge representation, we asked participants to apply the information from texts to answer application questions in Chapters 4 and 5. These measures revealed that information from

regular texts (Chapter 4) and refutation texts (Chapter 5) was applied to new situations, indicating that the knowledge representation was decontextualized. However, our measure of decontextualization is limited, because the link between the learning phase (i.e. reading texts) and the application phase (i.e. answering questions and reading texts) was quite clear: Both phases were part of a single testing session that took place in the same setting. This may not reflect the ability to apply information in a setting that is more different from the learning setting. To get a more accurate reflection of decontextualization of information measures should administer the text in situations that are more different. Barnet and Ceci's taxonomy could be used as a guideline to increase differences. For example, the learning and application phase could be situated in different rooms, with a greater time interval between them, and the texts could be embedded in several other texts to make the link less obvious.

This dissertation advances our knowledge about constructing knowledge representations by providing a clear definition of knowledge representations and by suggesting several factors that affect the construction of knowledge representations, based on an extensive search of the literature. Although these factors have not been empirically tested in the context of 'learning from texts' in ways suggested in the review, they are based on theories that are supported by studies in several other contexts. For example, the finding that repeatedly processing information leads to consolidation of that information is agreed on by most (if not all) scientists and evidence for this fundamental principle is numerous. This makes it reasonable to expect that the same applies to repeatedly processing information in texts.

The Development of Skills That Are Involved in Learning From Texts

In Chapter 4 integration across texts was compared for fourth and sixth graders. Contrary to expectation, the children in both grades showed similar integration behavior. The results suggest that both groups of children were able to activate information from previous texts during reading subsequent texts, and integrate information across texts in memory. There are several explanations for the lack differences between the grades. Integration performance may have reached ceiling levels either due to 1) fully developed integration skills for children in both grades, or 2) low task demands. The first explanation is inconsistent with a recent report showing that children in grade 6 struggle with tasks that require integration skills (Sabatini et al., 2014). This report suggests that children in grade six still need to develop integration skills to some extent. The second explanation therefore seems more likely: Advanced integration skills were not necessary, so all children were able to do the task.

One factor that may affect the development of skills that are involved in learning from texts but that is not included in this dissertation is background knowledge. The relation between background knowledge and future learning from texts is reciprocal: A knowledge advantage early in life can have profound effects on future learning, putting those who started with a lag even more behind as the years progress (the Matthew effect, see Stanovich, 1986). For example, several studies have shown that the knowledge gaps that exist between children from different economic backgrounds increases over the years (for a review, see Neuman, 2006). The importance of background knowledge on future learning can be illustrated with the following example. Consider students that learn about an unfamiliar concept (e.g. 'ibis'). When linking this concept to existing categorical knowledge that they already have (e.g. 'birds'), they do not have to encode information that is already encoded (e.g. 'feathers'), they only have to link the new concept to the category (e.g. 'an ibis is a bird). This example shows that having background knowledge about categories saves cognitive resources when learning new information and that these resources can instead be used to encode other information.

It is noteworthy that many cognitive functions necessary for learning start developing well before children receive formal reading instructions. Comprehension skills and background knowledge for example, develop by listening, communicating, observing and interacting with people but also by using animations, movies, etc. (for example, see Kendeou et al., 2005). This may help future learning from texts. For example, listening comprehension skills and vocabulary knowledge at pre-reading age have been demonstrated to be predictive of future performance in reading comprehension (Kendeou et al., 2009). Thus, development of skills involved in learning from texts starts early in life. Therefore, it is important to take experience at a pre-reading age into account when studying learning from texts.

Teaching Learning From Texts

By synthesizing previous research with the findings from the current dissertation several practical implications can be derived. Below a selection of practical interventions are suggested that may improve integration across texts and knowledge revision.

Integration across texts. The current dissertation shows that children are able to spontaneously activate information from previous texts during reading and integrate intertextual connections in memory, even when they have poor comprehension skills or poor working memory. This may seem in contrast with studies showing that children struggle with intertextual integration (Sabatini et al., 2014; Sheehan et al., 2006). As mentioned this discrepancy could be the result of differences in the materials used; the texts used in the studies

in this dissertation were quite easy and short. Thus, children are able to integrate information across texts, but there may be development in terms of the complexity of integration processes children can handle.

Our study indicates that children have a basic level of intertextual integration skills. However, in and outside schools children may have to process multiple texts in more challenging situations that require advanced intertextual integration skills. For example, children may need to integrate more than two texts when writing an essay. Although we did not investigate these situations, we can speculate which factors contribute to success or failure in integrating information across texts. First, information from previous texts needs to be available (either because information is still active or because information is encoded in memory). This can be accomplished by using memory strategies for example. Second, during reading subsequent texts, information from previous texts needs to be passively or strategically (re)activated. Passive activation processes are guided by featural overlap (Albrecht & Myers, 1998; Albrecht & O'Brien, 1993; Cook et al., 1998; McKoon & Ratcliff, 1980; O'Brien & Albrecht, 1991). This implies that as long as there is a cue available that related back to previous texts, children should be able to activate information from previous texts. This is a testable hypothesis that should be tested in the future. How many cues are required or how strong the cue must be may depend on the child and on the learning situation. If the goal is to acquire information from multiple texts, overlap must be optimized. But if the goal is to train integration skills it may be better to gradually decrease overlap. Once information from previous texts is (re)activated during reading connections across texts can be established. The third and final step involves encoding these connections in memory. Again, memory strategies can be used to accomplish this.

Interventions and strategies that promote prior knowledge activation have been studied extensively. Three examples of interventions or strategies that were originally used to study activation of prior knowledge will be described and extended to activation of prior *text information*. Small changes in these interventions or strategies may make them suitable for activating prior text information in multiple text situations.

First, self-explaining the text during reading helps students to activate prior knowledge, because activating prior knowledge is often necessary to comprehend the text (Chi, De Leeuw, et al., 1994). This strategy may therefore also be useful for reading multiple texts, because it may trigger readers to notice that they need information from previous texts in order to explain the current text. Students can be trained to improve their self-explanation skills. The Self-Explanation Reading Training (SERT) for example, improves students' ability to self-explain during reading (McNamara, 2004). Future studies could use the SERT in the context of multiple texts, to determine whether the training may be beneficial for reading multiple texts as well.

Second, graphic organizers stimulate readers to activate prior knowledge and relate this to information in the text (Ausubel, 1963). In graphic organizers information is visualized as nodes that are interconnected. Graphic organizers have been used to visualize information from single texts and its connections to background knowledge (for a meta-analysis, see Kim, Vaughn, Wanzek, & Wei, 2004). Similarly, graphic organizers may be used as scaffolds to activate prior text information and relate information across multiple texts. In a recent intervention children were taught to use graphs to activate prior knowledge to make gap-filling inferences in texts (Elbro & Buch-Iversen, 2013). These graphs were used to visualize missing links between sentences within a text, making students aware of the importance of prior knowledge activation. The intervention significantly improved reading comprehension ability, demonstrating that the skills that were taught transferred to situations without graphs. Teachers could construct similar graphs to stimulate students to activate information from prior texts and to connect information *across* multiple texts. This may help students to become aware of the importance of prior text activation during reading multiple texts. As a result, students may spontaneously activate information from prior texts in future situations in which they do not have graphs to scaffold this process.

Third, pre-reading activities have been shown to activate prior knowledge. Teachers can organize classroom discussions in which students share personal experiences that relate to the topic of the text before reading (Au, 1979; Langer, 1981) or they can ask specific questions that trigger students to activate prior knowledge (Graves & Graves, 2003; Reutzel, 1985). Students can be asked to predict the content of the text based on previewing text, for example by reading the titles and looking at the pictures in the text (Graves, Cooke, & Laberge, 1983). A similar approach can be applied in the context of multiple texts, but using prior texts as sources of information. For example, teachers could ask students to recall what they have read in previous meetings in subsequent lessons.

The activities self-explaining, using graphic organizers and pre-reading were explained in the context of children in classrooms, but obviously these activities may also be appropriate for adults. Adult readers are probably more skilled at integrating information across texts due to experience, but the demands for this population are also higher. This may put them at risk for failing to integrate information across texts. One challenge is the absence of a teacher and consequently increased personal responsibility to select and integrate information across texts. When future research has established the conditions

in which adults fail to integrate information across texts, adult readers can be made aware of possible pitfalls and they can be explained ways to avoid these pitfalls (such as by using the three activities that are described in the previous paragraphs).

Knowledge revision. Chapter 5 demonstrated that refutation texts are effective for revising knowledge and applying revised knowledge in new situations. A practical implication is that teachers can use refutation texts to accomplish these goals in schools, at least when it concerns misconceptions that can be represented by a single idea. The advantage of using refutation texts is that they can be disseminated to a large group of students at the same time. Students simply have to read a text and no other preparations are necessary.

The underlying principles that are used to explain the effectiveness of refutation texts are: Co-activation, integration and competing activation (Kendeou & O'Brien, 2014). Other methodologies that are based on the same principles may also be useful for revising knowledge. For example, compare-contrast text structures (that lack explicit refutations) could trigger these processes as well. In compare-contrast text structures two opposing positions are described and compared, focusing on similarities and differences. This naturally involves activating two positions at the same time (i.e. co-activation), which could lead to integration and, if one position is clearly favored (e.g. by a convincing explanation), dominance of one position in the mental representation. Compare-contrast texts can be made even more effective by *training* students to process texts with a compare-contrast structure (for a review, see Meyer & Ray, 2011), for example by teaching them to focus on words that signal comparisons (such as 'however' or 'in contrast'). However, this requires a text to explain both the incorrect and the correct depiction of the situation in one text. These texts are not always available and may therefore need to be construed by teachers. A different approach is to collect two texts with opposing positions, one describing the correct and the other the incorrect depiction of the topic. In this situation, interventions such as those suggested in the previous paragraph in the context of multiple texts could be used to achieve co-activation (e.g. by having students self-explain the text).

Other types of interventions that were originally designed to facilitate solving analogies and constructing abstract representations from multiple examples may be informative for revising knowledge as well. These two activities have in common that both involve relating information, identifying relevant similarities and ignoring irrelevant differences. In the case of analogies this involves recognizing that 'deep' structures of the analogies are similar whereas superficial structures may differ. In the case of abstraction this involves recognizing that examples share characteristics that belong to one abstract category, but may

differ with respect to characteristics that are irrelevant to the abstract category. Interventions that have been suggested in these domains improve the ability to relate information across analogies or examples, so similar interventions may be useful in the context of relating correct and incorrect information. For example, it has been demonstrated that providing hints improves the ability to solve analogies (for a review, see Day & Goldstone, 2012). Similarly, hints could be used to remind students that their (incorrect) prior beliefs were false and this may improve maintenance of the revised knowledge in memory. For example, teachers can provide students with hints that consist of refutations with short explanations each time the topic is discussed in the classroom (i.e. "Remember that you thought X, but then you learned that it is actually Y, *because* Y… ").

Conclusion

The aim of this dissertation was to gain insight into the processes that are involved in the construction of knowledge representations from texts in both adults and children. A literature review and three empirical studies were conducted to achieve this aim. All empirical studies demonstrate that both adults and children are able to learn information from texts spontaneously: Previously read texts help them to extend and revise their knowledge. This dissertation includes innovative research methods that can be used in follow-up research to determine which factors affect knowledge extension and revision in more challenging situations. The literature review could inspire future research to determine which factors should be investigated in follow-up studies. Eventually, these studies may lead to practical interventions. Interventions that are proven effective should then be integrated into school curricula. Hopefully, this dissertation will motivate other researchers to follow up on the line of research that was presented in this dissertation. This will bring us closer to achieving one of the most important 21st century goals. That is, enabling students of all ages and differences in cognitive abilities and background knowledge to construct permanent and decontextualized knowledge representations from multiple (digital) texts.