Learning from texts : extending and revising knowledge

Beker, K.

C H A P T E R

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Meaningful Learning From Texts: The Construction of Knowledge Representations

Accepted for publication
Beker, K., Jolles, D., & van den Broek (in press). Meaningful learning from texts: The construction of knowledge representations. In I. Escudero & J. A. Léon (Eds.), *Reading Comprehension in Educational Settings*. Amsterdam, The Netherlands: John Benjamins.

Introduction

The main goal of formal education is to provide students with high-quality conceptual background knowledge that they are able to apply, both inside and outside of the academic situation in which they acquired it. This knowledge can be used to manage everyday situations (taking care of bills, reading formal letters) and to perform well in more advanced educational and professional settings (Barnett & Ceci, 2002). Conceptual knowledge can be acquired in many different ways, but a substantial amount of conceptual knowledge is delivered by using texts in some form –e.g., expository print, digital texts. Although it is possible to memorize information in such texts by rote learning of superficial textual features, meaningful learning requires a deep level of comprehension.

In the past decades, knowledge about learning from text has mainly focused on what is remembered from short, single, and often narrative texts directly after reading. However, recently there has been more attention for deeper *learning* from texts, which often involves integration of longer, multiple, expository texts. In accordance with this development, the goal of this book chapter is to describe the processes that are involved in meaningful learning of conceptual knowledge. In doing so, we pay particular attention to the interplay between learning and comprehension. Consideration of this interplay is important for various reasons. One reason is that comprehension is a necessary component of meaningful learning -although, as we will argue, not a sufficient one. A second reason to consider comprehension in the study of learning is the fact that prior research has yielded a detailed understanding of the processes and products of comprehension, which can provide a useful foundation for investigating processes and products in learning. Reading comprehension theories are not only informative about the way texts are comprehended but also about the cognitive architecture that is involved in general comprehension, reasoning, problem solving, and learning (McNamara & Magliano, 2009). All of these processes involve key elements that are well described in the reading comprehension literature, such as activation of prior knowledge, integration of information, validating information, process monitoring, memory, and so on. Reading comprehension theories therefore can form the basis for understanding learning from texts. In this book chapter we describe the processes and strategies that contribute to meaningful learning from texts. We combine insights from the reading comprehension literature and from the learning literature to gain a better understanding of the underlying mechanisms involved in learning from text. In doing so, we consider both the processes and the products of learning. We conclude by discussing important questions that may be fruitful directions for future research.

The Products of Learning: Knowledge Representations

Learning and Comprehension

It is important to describe what we mean by learning and how that differs from comprehension. Many researchers use similar definitions to describe comprehension and learning. For example, Kintsch (1980) defines comprehension as “the process of continuous modification of knowledge structures”, and learning as “the transformation of knowledge structures”. Moreover, comprehension and learning are frequently used interchangeably, without defining differences. It is theoretically as well as educationally relevant to differentiate between the process of creating a meaningful mental representation of a text during reading, to which we refer as comprehension, and the encoding of that information in long-term memory, to which we refer as learning. Comprehension involves building a mental representation of the text (often called a situation model) in which features from the text and knowledge retrieved from long-term memory are integrated. In contrast, learning is defined as a *relatively permanent change in knowledge and behavior as a result of experience* -in this case: reading-, i.e., a relatively long-term change in the reader’s knowledge representation itself (Shuell, 1986). In the case of knowledge acquisition through reading this relatively permanent change requires that the presented information is encoded in a mental representation that is accessible at later points in time. Whether reading was successful in changing the knowledge representation permanently can therefore only be examined after passage of time.

Reciprocal Relation between Learning and Comprehension

The fact that comprehension and learning are often used interchangeably may be due to the reciprocal relation between them. Reading and comprehending texts can result in learning from these texts, and knowledge that is learned from these texts can, in turn, be used to facilitate comprehension and learning from subsequent texts (Adams, Bell, & Perfetti, 1995; Britton, Stimson, Stennett, & Gülgöz, 1998; Cook, 2005; Kendeou et al., 2003; McNamara, Kintsch, Songer, & Kintsch, 1996; Ozuru, Dempsey, & McNamara, 2009; Recht & Leslie, 1988). That comprehension affects learning is illustrated by the finding that textual adaptations aimed at improving comprehension also improve learning (Britton & Gülgöz, 1991; Gilabert, Martínez, & Vidal-Abarca, 2005; McNamara et al., 1996). Moreover, individuals with good comprehension skills often learn better, as reflected by higher academic science achievements, than do individuals with poor comprehension skills (O’Reilly & McNamara, 2007). But knowledge (the result of learning) also affects comprehension. For example, an important aspect of comprehension is making inferences: Drawing on background knowledge to identify relations that are implied by the text or to

activate information that is not explicitly mentioned in the text. The importance of knowledge in comprehension is illustrated by the following example: It is easier to comprehend the sentence “Kevlar sails were used because there was little wind” if one has knowledge about the characteristics of Kevlar sails (Noordman & Vonk, 1992). Moreover, high levels of background knowledge can compensate for poor comprehension skills. It has been demonstrated that poor comprehenders with elaborate knowledge about a certain topic are able to reach the same level of understanding as good comprehenders when reading a text that relates to their knowledge (Recht & Leslie, 1988).

Knowledge Representations

When learning from texts is successful, it leads to a (relatively permanent) representation in long-term memory, i.e., a knowledge representation. There are several models of long-term memory representations. These models differ in the way knowledge is organized in memory, the level of granularity in which knowledge is represented, and the way knowledge representations are thought to develop. It is beyond the scope of this chapter to provide a full review of these models but see McRae and Jones (2013) for a recent overview. Most recent models assume that knowledge is represented in structured networks of interconnected nodes. Kintsch, for example, describes such knowledge structures to represent conceptual knowledge (Kintsch, 1988), with nodes referring to concepts or propositions and links between the nodes to relations between the concepts or propositions. The links represent associations between nodes, and these links can vary in strength.

The long-term availability of knowledge structures depends on the coherence of knowledge structures. For example, it is easier to remember logically ordered information than arbitrarily ordered information (Bauer, 2013). It has been hypothesized that knowledge representations in memory are organized based on shared semantic characteristics and/or associations (McRae & Jones, 2013). In line with this view, knowledge structures facilitate learning in three ways. First, knowledge structures facilitate encoding (R. C. Anderson, 1984; Brewer & Treyens, 1981; Tse et al., 2007). Consider learning that the ibis has multiple characteristics (e.g., it has feathers, it flies, it has long legs, etc.) and that it is related to ‘birds’. By linking ‘ibis’ to the knowledge structures that represents ‘birds’, a learner does not need to encode all characteristics related to ‘birds’, but instead only encodes that the ibis is a bird (Collins & Quillian, 1969). This makes it easier to encode other characteristics of the ibis. Second, knowledge structures facilitate retrieval. Knowledge structures (e.g., ‘birds’) incorporate a collection of characteristics (e.g., feathers, flying, beaks), thereby providing multiple retrieval cues to the target concept (i.e., ‘ibis’) (R. C. Anderson & Pichert, 1978; Bransford & Johnson, 1972; Rawson & Kintsch, 2002, 2004; Spilich, Vesonder, Chiesi, & Voss, 1979; Voss, Vesonder, & Spilich, 1980). Third, knowledge structures facilitate spontaneous learning of information that was not presented. For example, when learning that the ibis is a bird the learner may also encode that the ibis lays eggs, even if this was not explicitly stated. This may occur through an inference triggered by shared characteristics or associations with knowledge already represented in memory. The ibis-example shows the importance of having coherent knowledge representations in memory. How coherence is established over the course of development is still a point of discussion (McRae & Jones, 2013).

The ultimate goal of learning is creating a high-quality knowledge representation. By comparing the knowledge representations of experts and novices, we can gain insight into the characteristics of high-quality knowledge representations. Experts differ from novices in the amount and quality of knowledge they have, which is often a result of extensive experience and deliberate practice (Ericsson, Krampe, & Tesch-Römer, 1993). Another characteristic of expert knowledge is that it is decontextualized, meaning that knowledge is not tied to a specific learning context. As a result the knowledge can be applied to a wide range of situations, a process called *transfer*. Experts’ extensive knowledge is organized in chunks of concepts that are highly associated to one another and only weakly associated with elements of other (less related) chunks. The organization of knowledge in chunks helps experts to recognize and remember more complex problems compared to novices (Newell & Simon, 1972). Moreover, their extensive background knowledge provides more possibilities to relate new knowledge to an existing knowledge structure, thereby facilitating encoding (Spilich et al., 1979). In contrast, knowledge of novices is often limited, lacks coherence and is more dependent on the context (DiSessa, Gillespie, & Esterly, 2004). Moreover, knowledge of novices is often influenced by misconceptions. These misconceptions arise from naïve theories about the world based on intuition and perception (Vosniadou & Brewer, 1992).

Based on this brief summary of research comparing experts and novices, it can be concluded that a high-quality knowledge representation is extensive, organized, and decontextualized. In addition, high-quality knowledge is accurate, meaning that it coincides with the community’s (e.g., teacher, text book) prevailing standards (e.g., of the teacher, the textbook). Novices become experts with accumulated experience and practice, but the question is how information that is encountered in a text for the first time eventually becomes high quality knowledge. According to Kintsch (1988), knowledge representations are relatively fixed and cannot flexibly adapt to the continuously changing situation as a reader progresses through the text. If knowledge representations would

be constantly updated, these representations would fail to reach the level of permanency necessary to be functional. The text representation therefore serves as an intermediate level of representation, between the text and the knowledge representation. With each new sentence, the representation of the text is being updated to incorporate the incoming information. This intermediate level of text representation allows the reader to represent a flexible and temporary situation that is true for a given text without leading to immediate permanent changes in knowledge. Text representations could lead to changes in knowledge representations, but this depends on the situation (more details about those situations that lead to learning are described later in this chapter) (Kintsch, 1988).

Text Representations

Text comprehension is a reading process that results in the construction of a mental representation of the text that is analogous to a mental representation of knowledge in long-term memory (Kintsch, 1988). Similar to knowledge representations, text representations can be depicted as networks, with each node representing text information or related background knowledge, and each link representing the relation between the nodes. The nodes can represent text information or background knowledge of various grain sizes: Individual words, propositions, paragraphs etc. The links can represent various relations, but it is common to represent the text as a network of causal and referential relations (Graesser et al., 1994; Kintsch, 1988; van den Broek, 1988, 1989a, 1989b, 1990). The relations vary in strength, for example some story events ('pushing a vase') are stronger causes of subsequent events ('the vase breaks') than other causes ('touching a vase'). When comprehension is successful, the representation of the text contains individual text elements that are related to each other, as well as to relevant background knowledge. Thus, an important characteristic of text representations is that they consist of both explicitly mentioned information from the text and implicit information that is inferred from the text and the reader's background knowledge.

To be successful at comprehending a text, readers must attain coherent representations of the text. Coherence can be accomplished by organizing text representations in a certain way (e.g., Trabasso, Secco, and van den Broek (1984); (van den Broek & Gustafson, 1999). First, text representations are organized to fit mental schemata that readers have of different text structures. Most narratives have similar text structures and the ordering of text elements in a narrative tends to adhere to similar rules across different stories (i.e., most stories start with a setting, then an event is described, leading to a goal to be accomplished by the protagonist and attempts to reach that goal, etc.,

see research on story grammars (e.g., Mandler & Johnson, 1977; N. L. Stein & Glenn, 1979). Text representations that readers construct from a text are likely to include information that fits these story schemata (Mandler & Johnson, 1977). Discrepancies between the reader's text representation and information presented in the text (e.g., recall of information that was not described in the text, or recall of the text events in a different order) can sometimes be attributed to deviations of the texts from story schemata and are caused by the tendency to map text representations onto known story schemata (e.g., Bartlett, 1932). Expository texts have more diverse structures than narratives do, but nevertheless common expository text structures have been identified, including comparison, problem/solution, causation, and collections of descriptions (Meyer & Freedle, 1984; Ray & Meyer, 2011). Similar to representations of narratives, readers' text representations of expository texts are often structured in a way that matches the readers' text schemata (Meyer, Brandt, & Bluth, 1980).

Second, coherence of a text representation can be increased by including meaningful relations between text elements. The nature of these relations depends on the situation, but causal and referential relations seem to be included most frequently (Kintsch, 1988; McNamara, 2007; Trabasso et al., 1984; van den Broek, 1988, 1990). Other types of relations involve spatial, temporal, motivational, and emotional relations (Graesser & Clark, 1985; Schank & Abelson, 1977; van den Broek & Gustafson, 1999; Zwaan, Magliano, & Graesser, 1995). Relations are not always explicitly stated in the text, and therefore often need to be inferred based on background knowledge. These inferred relations further strengthen a text representation. In summary, coherence can be accomplished by using common text schemata to organize text representations and by incorporating (causal) relations between text elements into text representations (Trabasso & van den Broek, 1985).

To determine the characteristics of *high quality* text representations it is informative to compare the text representations of good and poor comprehenders. An important difference between these groups of readers concerns the extent to which their text representations contain literal information from the text relative to information that can be inferred from the text (Collins & Quillian, 1969; Fletcher, Chrysler, van den Broek, Deaton, & Bloom, 1995; van den Broek & Gustafson, 1999). Poor comprehenders have the tendency to extract more literal (text-base) information from the text than good comprehenders (McMaster et al., 2012), whereas good comprehenders infer more of the situation that is conveyed by the text (O'Brien, Albrecht, Hakala, & Rizzella, 1995) and, as a consequence, represent more gist information in their text representations (Bean & Steenwyk, 1984; Chi, De Leeuw, Chiu, & Lavancher, 1994; Wong, 1985). Similarly, good comprehenders incorporate more background knowledge

in their text representations to create coherence. A second important difference concerns the extent to which readers incorporate central information in their text representation. Good (i.e., more skilled or more developed) readers include more central information than poor readers (van den Broek, 1989b; Wolman, van den Broek, & Lorch, 1997). In addition, good readers include less inaccurate information and their text representations are more organized (Elbro & Buch-Iversen, 2013; J. R. Miller & Kintsch, 1980). Overall, poor readers recall less information from the text after reading (J. R. Miller & Kintsch, 1980).

From Text Representations to Knowledge Representations

In the preceding sections we have described that text and knowledge representations can both be described as interconnected mental representations. The difference between text and knowledge representations is best illustrated by comparing their permanency and degree of decontextualization. Text representations are quite temporary and closely linked to the text, whereas knowledge representations are more permanent and decontextualized. Learning starts with creating a mental representation of the text (Figure 2.1, black upward arrow). The construction of a text representation is influenced by background knowledge (black downward arrow). The text representation can gradually evolve to become part of one's knowledge representation, a process we call learning (white arrow). It should be noted that even though in the figure the distinction between text representation and knowledge representation is portrayed as dichotomous, in reality the two types of representation may be best described as being on a continuum. Whether a text representation eventually becomes a knowledge representation depends on the processes that occur during reading, which will be described next.

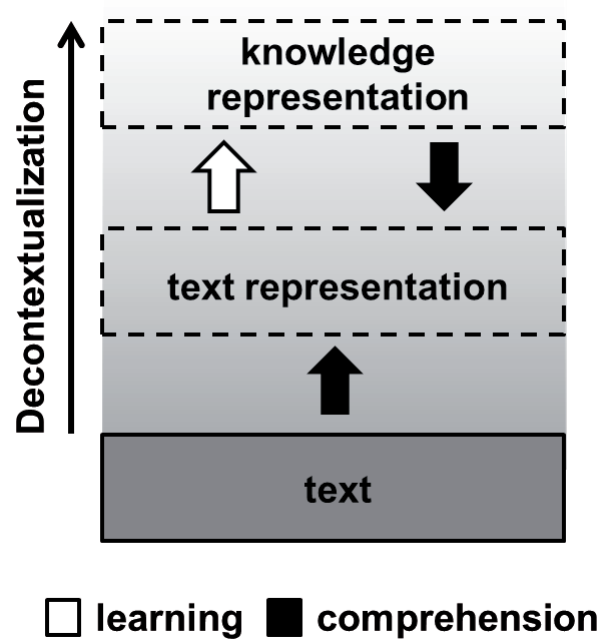

Figure 2.1 Representations in comprehension and learning.

The Processes That Contribute to Learning from Texts

The construction of a mental representation relies on an intricate combination of cognitive processes. With respect to the construction of a representation from a text, these processes are described in great detail in current models of reading comprehension (see McNamara & Magliano, 2009, for a review). In comparison, little is known about the processes by which a learner constructs or updates a knowledge representation. What is known about the processes by which readers construct a text representation may be very useful to gain insight in the processes by which a learner constructs a knowledge representation (Kirby, Cain, & White, 2012; McNamara & Magliano, 2009). In both contexts the crucial component is the identification and integration of semantic relations into a representation. Research on text comprehension has shown that there are two types of processes that contribute to the construction of text representations: Passive and strategic processes. These types of processes are likely to play a role in the construction of knowledge representations as well. In the following sections we discuss passive and strategic processes as they take place when constructing text and knowledge representations.

Passive Processes

According to models of text comprehension, information needs to be activated in working memory in order to become part of a representation (Albrecht & O'Brien, 1993; Kintsch, 1988; van den Broek, 1995). Activation can occur through passive processes that are not under the control of the reader (Gerrig & McKoon, 1998; McKoon, Gerrig, & Greene, 1996; Myers & O'Brien, 1998; O'Brien, 1995). Memory-based models of text comprehension propose that, as the reader proceeds through the text, information from the text automatically activates information from previous parts of the text that are related to the concepts that are being read (Albrecht & O'Brien, 1993; Klin & Myers, 1993; O'Brien, Duffy, & Myers, 1986; van den Broek, Young, Tzeng, & Linderholm, 1999). Background knowledge that is associated with the information in the text also becomes activated, as a result of a spread of activation through concepts that have overlapping semantic and contextual features (Gerrig & O'Brien, 2005). The process of spread of activation is passive, dumb, and unrestricted (Gerrig & O'Brien, 2005). It is passive in that it occurs without active effort or control on the part of the reader. All knowledge that is associated with the text that triggered the activation becomes activated. The process is dumb in that activation is based on superficial characteristics. For example, even refuted knowledge becomes activated if it has some degree of associative overlap with concepts in the currently read sentence (O'Brien, Rizzella, Albrecht, & Halleran, 1998). Finally, it is unrestricted in that information from the text activates all associated information, even if that information does not contribute to understanding of the text (Cook, Halleran, & O'Brien, 1998). For example a sentence such as 'he bought her a ring' can activate associations that relate to ringing a bell.

The information that is most strongly activated will enter working memory (Myers & O'Brien, 1998; O'Brien & Myers, 1999). Several factors have been found to influence the extent to which a concept is activated. Among them are a) the frequency with which the memory trace is activated (either directly by repetition in the text, or by featural overlap with other concepts), b) the amount of elaboration on the concepts in the text, c) the richness of the interconnected network of the concept in memory, d) the presence of distractors, and e) the focus of attention (Albrecht & O'Brien, 1993; Cook et al., 1998; Garrod, Freudenthal, & Boyle, 1994; Gerrig & O'Brien, 2005; O'Brien, Raney, Albrecht, & Rayner, 1997; O'Brien et al., 1998). In addition, the extent of activation depends on the type of information. Information that provides causal explanations and referential grounding is particularly likely to be activated, as this type of information is inherently interconnected (Kendeou, Smith, & O'Brien, 2013; O'Brien & Myers, 1987; Trabasso & van den Broek, 1985).

When multiple pieces of information are simultaneously active in working memory, relations can be formed (van den Broek & Kendeou, 2008). A common distinction is made between relations between different parts of the text (connecting/bridging inferences) and relations between the text and background knowledge (knowledge-based inferences). The first may be the result of close proximity of two pieces of information in the text or reactivation of previous text information, resulting in co-activation (O'Brien, 1987; O'Brien et al., 1995; O'Brien, Plewes, & Albrecht, 1990). The second is the result of activation of background knowledge through associations or cues that are activated by the currently read text or stated in close temporal proximity to the text (Myers & O'Brien, 1998). An example of a connecting /bridging inference is when 'Lauren' is related to 'she' when reading: "Lauren likes animals. She does not eat meat". An example of an knowledge-based inference is when a reader relates the statement that Lauren does not eat meat with the statement that she likes animals, as 'eating animals' in the text may have activated the background knowledge that animals in the meat industry are not treated well.

According to the Landscape Model (Linderholm, Virtue, Tzeng, & van den Broek, 2004; van den Broek et al., 1999), the text representation is a direct result of the amount of activation during reading: The stronger concepts are (co-) activated during reading, the more likely it is that they enter working memory and that they (and their relations) become part of the text representation. Computer simulations of the reading process based on the Landscape Model suggest that activations during reading are indeed highly predictive of the resulting text representation (van den Broek, Risden, et al., 1996). In particular, activation of causal and referential information seems to be a major predictor of whether information is included in text representations. Similarly, by investigating readers' summaries and recall of texts, it has been found that the number of causal relations that a concept has in the text and whether the concept is part of the causal sequence of events (causal chain) in the text, are strong predictors of the inclusion of the concept in a text representation (Trabasso et al., 1984; Trabasso & van den Broek, 1985; van den Broek, 1988; van den Broek & Trabasso, 1986).

Passive processes such as those that influence the construction of a mental representation of a text are also likely to play a role in the construction of knowledge representations in the context of learning. Knowledge representations can be the result of reading text parts once, but more frequently they are the result of reading text parts repeatedly. Multiple encounters with texts about the same topic increase the activation of particular pieces of information, thereby stimulating more permanent encoding. There is a vast amount of literature supporting claim that repetition (by reinstatements or rereading) facilitates long-term memory

(Amlund, Kardash, & Kulhavy, 1986; Bromage & Mayer, 1986; Mayer, 1983). Eye-tracking methods show that rereading results in faster reading of already processed materials (Foster, Ardoin, & Binder, 2013; Raney & Rayner, 1995), indicating that the information is familiar and, thus, that it has been encoded in memory. Once information is encoded in memory more attention can be devoted to other information during rereading, which consequently is likely to improve memory for the other information as well (Samuels, 1979).

Furthermore, repeatedly encountering the information in *different* contexts, for example by reading different texts about the same topic, facilitates encoding even further by fostering more elaborate and more densely interconnected networks of knowledge. For example, new vocabulary is learned better in variable contexts than repeated exposure in the same context (J. R. Anderson & Reder, 1979; Bolger, Balass, Landen, & Perfetti, 2008). The explanation for this is that the mental representation of the information is enriched by the many relations and concepts that are activated by the varied contexts (Craik & Lockhart, 1972). This is turn facilitates retrieval, because multiple cues that are available lead to access of the information in memory. Experiencing information in various contexts also facilitates the process of decontextualization; it allows for comparisons across situations, enabling one to extract the commonalities across different contexts and to ignore what is context-specific (Chen & Daehler, 2000; DiSessa & Wagner, 2005; Fuchs et al., 2003; Lobato, 2006). As a result, the possibility that the learners will recognize that the learned information applies to a new situations increases (Bransford, Brown, & Cocking, 2000). We will return to the issue of learning from multiple texts below.

Strategic Processes

Activating information from memory and making inferences can also result from a deliberate act by intentionally directing attention to specific information. The main difference between passive and strategic learning processes is that strategic learning processes are goal-directed and volitional. Strategic processes are effortful and deliberate but with practice they may become automatized (Afflerbach & Cho, 2009). In reading comprehension a more effortful strategic approach is often triggered when automatic processes do not lead to a sufficient level of comprehension. Evaluation of the level of comprehension is based on the reader's standards of coherence (van den Broek, Bohn-Gettler, Kendeou, Carlson, & White, 2011; van den Broek, Risden, & Husebye-Hartman, 1995). These standards reflect the degree of comprehension that the reader wants to attain. When the standards are not met through automatic processes, strategies can be used to reach a sufficient level of comprehension. A reader may also have learning standards that reflect the degree of learning the learner wants to

attain. Even when readers believe that they have sufficient comprehension of the text to meet their comprehension standards, it is possible that they implicitly or explicitly feel that they have not reached the level of learning they want to attain. When the learning standards are not met learning strategies may be used to reach the desired level of learning. Unfortunately, it is difficult to judge during reading whether something is learned or not (Thiede, Anderson, & Therriault, 2003). Readers often base their judgments about future retrievability of information on current retrievability of the information, however immediate recollection does not always relate to delayed recollection (Thiede & Anderson, 2003).

Several strategies can be used to learn from texts. The list of strategies described in the following paragraphs is not comprehensive, but includes a selection of strategies that are promising for improving meaningful learning from text. Strategies that improve learning from texts can be divided in three categories: Strategies that target reading comprehension processes, strategies that target retention/memory processes, and strategies that target transfer processes. A combination of these three types of strategies is most likely to contribute to meaningful learning from texts. Of course, strategies that target one of these processes often also improve the other processes.

The first set of strategies target different components of reading comprehension. These strategies can be used before, during, or after reading and all focus on relating different pieces of information within the text and the reader's background knowledge to create a strong, coherent representation of the text. The most effective strategies focus on inference making (Elbro & Buch-Iversen, 2013; McMaster et al., 2012), self-explaining the text (McNamara, O'Reilly, Best, & Ozuru, 2006), self-questioning (Wong, 1985), organization (summarizing, overviewing before reading, reading titles) (Afflerbach & Cho, 2009; Bean & Steenwyk, 1984; Rinehart, Stahl, & Erickson, 1986), directing attention (adjusting reading speed, focusing attention on important information, reading titles, applying reading goals), rereading and looking back in the text (Afflerbach & Cho, 2009), text structure (detecting signal words in text with compare-contrast formats) (Meyer et al., 1980; Meyer & Poon, 2001), and comprehension monitoring (Chan, Cole, & Barfett, 1987). Comprehension strategies are often also effective in improving retention of the text; something that has been comprehended is retained better than something that has not been not comprehended (Morris, Stein, & Bransford, 1979).

The second set of strategies target retention processes. The goal of these strategies is to create durable memory traces for the learning materials, to enable learners to remember the information over time, often regardless of comprehension. The effectiveness of most of these strategies have been

demonstrated mainly with simple learning materials such as word pairs, but some of these strategies have also been applied successfully to learn from more complex and educationally appropriate learning materials such as texts (Roediger & Pyc, 2012). Common retention strategies are: (distributed) rehearsal (repeated studying) (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Newell & Rosenbloom, 1981), elaboration (relating learning material to prior knowledge) (Bradshaw & Anderson, 1982), organization (for example with graphic organizers) (Novak, 1990), and retrieval practice (Bjork, 1975).

The third set of strategies target transfer processes. Even though comprehension and retention are necessary for transfer, they are not sufficient (Royer, 1979). Transfer is the process of applying knowledge in novel situations that are distinct from the situations in which the knowledge was learned (Day & Goldstone, 2012). Central to this definition of transfer are the components 'novel' and 'distinct', implying that transfer strategies should focus on recognizing that a novel context (to which the knowledge has to be applied) has similarities with the context in which the information was learned, and ignoring differences between the situations that are not relevant. Strategies that are successful in improving transfer are therefore strategies that focus on making comparisons and relating multiple examples of similar and different concepts (Richland, Stigler, & Holyoak, 2012), self-explaining (Chi, Bassok, Lewis, Reimann, & Glaser, 1989), looking for cues that expose the deep similarities between the novel situation and background knowledge (Chi & VanLehn, 2012), and generating examples to create awareness of the broad applicability of information in different contexts (Engle, 2006; Engle, Lam, Meyer, & Nix, 2012).

Together these three sets of strategies enable the learner to effectively encode textual information to his or her permanent store of background knowledge. Each learning situation requires a different set of strategies and readers have the challenge to select and apply the right strategies from their repertoire to accomplish a sufficient level of comprehension and learning. For example, a student may need strategies that target comprehension, retention and transfer when learning about the digestive system in a textbook, whereas only strategies that target retention are necessary when learning about the gender of nouns in Spanish from a book. Good learners are flexible when switching between different learning situations such as described in these examples.

Mechanisms

The mechanisms that underlie the strategies that were described in the previous section can be divided into two categories: Consolidation and enrichment of the mental representation. In terms of mental network models discussed above, consolidation involves strengthening the nodes and relations that make up the knowledge representation that is gained from the learning experience, and enrichment involves elaboration and expansion of the knowledge representation. Note, however, that most strategies incorporate both mechanisms, thereby contributing to the effectiveness of the strategies.

Consolidation and enrichment mechanisms also have been used to explain why strategies that require more effort and deep processing are generally more effective (Craik & Lockhart, 1972; Slamecka & Graf, 1978), even though students prefer easy ways of learning (Bjork, 1994; Schmidt & Bjork, 1992). Actively generating information (which requires effort) is argued to strengthen information and relations in memory (consolidation) (Hirshman & Bjork, 1988), and to reactivate related information from memory which may result in relations with prior knowledge (enrichment). Deep processing (which often involves extracting meaning) is argued to involve elaboration and, as a result, enrichment of the representation (Bradshaw & Anderson, 1982).

Learning from Multiple Texts

Multiple Text Representations

In the preceding sections, we have described how information extracted from a text is gradually incorporated into a mental representation of the text and, in case of learning, into a knowledge representation. Frequently, learning involves integration of information from multiple texts because learning complex concepts requires multiple learning episodes and because a single text almost never provides all the necessary information (Britt & Rouet, 2012). Thus, many educational tasks require students to search for multiple texts and to create a single mental representation encompassing the information from the multiple texts. Examples of such tasks are writing essays, preparing presentations, and reading multiple chapters of a book for a test. Comprehending multiple texts requires skills that differ, in part, from those required for comprehending single texts. The Documents Model (Britt et al., 1999; Britt & Rouet, 2012) proposes that comprehension of a single text leads to building a mental representation of that particular text, and that comprehension of multiple texts requires in addition, an *intertext model*, incorporating a representation of the source of the texts. This includes information that qualifies the text, such as information about the author, where the text was encountered, etc. The *intertext model* also includes information about how multiple texts relate to each other in terms of content and author. For example, two texts could be classified as being inconsistent with each other, or as presenting opposite views. Multiple text comprehension also requires the creation of a single integrated representation of the content information from the multiple texts (*integrated mental model*).

This representation includes content information that is abstracted from multiple texts and is integrated with background knowledge. It is likely that the intertext model and the integrated mental model interact with each other. Tagging a source as unreliable may lead to exclusion of information from the text in the integrated mental model. Moreover, a text may be represented as reliable when it describes information that was already central in an integrated mental model that has been constructed based on previous texts.

Passive Processes

Reading multiple texts about a topic can be a powerful way to enhance learning, because repeated exposure to information in different contexts may create strong and rich knowledge representations that are decontextualized. A challenge in integrating multiple texts is relating pieces of information from different texts that do not co-occur within each text. Learning relations requires simultaneous activation of the components that are part of the relation (i.e., co-activation) and hence can become related. One way to improve the likelihood of co-activation of specific concepts is to use clues in one text that prompt spontaneous reactivation of information in the other texts (Bauer, King, Larkina, Varga, & White, 2012; Bauer, Varga, King, Nolen, & White, 2015). Bauer and colleagues (Bauer et al., 2012; Bauer & San Souci, 2010; Bauer et al., 2015) studied factors that facilitate integration from multiple auditory narratives that are also relevant in the context of integrating information from multiple texts. Their results showed that integration is facilitated by surface similarity -in this case because each story involved the same protagonists- as well as prompts that link to previously presented narratives (Bauer et al., 2012; Bauer et al., 2015). Similarities and prompts may reactivate information from previous experiences, leading to co-activation and, as a result, integration of the information in memory.

Strategic Processes

Multiple texts may be similar, different, overlapping, or inconsistent with one another, and strategies should be used to generate a coherent mental representation that incorporates these intertextual relations (Lenski, 1998). The relations between multiple texts are often not described explicitly, so it is important that reading strategies target generation of these relations by the readers. Research focusing on compare-contrast text formats in single text learning can be used as a stepping stone for understanding integration of information from multiple texts. Readers find it difficult to read single texts with compare-contrast text formats (Englert & Thomas, 1987), but clue words that signal relations between text parts (e.g., “in contrast, …”) improve comprehension (Williams et al., 2005). These findings suggest that it may be useful to teach learners reading

strategies for generating clue words that relate information from different texts and, thereby, enable the reader to make the relations between the different texts more explicit. Likewise, interventions that improve knowledge about text structure of single compare-contrast texts (Meyer & Ray, 2011; Williams et al., 2014) could inform about how to improve integration of multiple texts. For example, in one study (Williams et al., 2005) children were taught to answer text-structure-focused questions such as “What two things is this paragraph about? How are they the same? How are they different?”. Similarly, children could be taught to answer questions such as “What things are these texts about? How are they the same? How are they different?”. Other strategies that may be used to make between-text relations are self-explanation and self-questioning (D. K. Hartman, 1995). Finally, as texts may differ in terms of reliability, strategies that help judging the importance, quality, and trustworthiness of the source are necessary to differentiate between conflicting accounts (Braasch, Bråten, Strømsø, Anmarkrud, & Ferguson, 2013; Bråten, Strømsø, & Britt, 2009; Britt & Rouet, 2012; Wiley et al., 2009) and to make the selection of information that will form the final knowledge representation.

Reader and Text Characteristics

Educators have the challenging task to support students who struggle with learning from texts. They have to identify students’ abilities and select (or write) texts that fit their educational needs. Failures to identify the causes of problems with learning from texts can have major implications for students’ educational careers. A comprehension problem in the early grades impacts knowledge acquisition, which on its turn affects future comprehension, leaving students with a knowledge gap that increases over time. Consider the findings reported by Hart and Risley (1995), that the breadth of vocabulary of high-performing students is twice as large as that of low-performing students in 1st grade, but four times as large in 12th grade. Likewise, there are consistent developmental differences in children’s comprehension and learning skills. It is important to be aware of such differences in both research and educational contexts.

Given the increasing use of texts as a source of knowledge as children progress in schools, the necessity to identify individual and text factors that explain differences in learning from texts becomes even more important in higher grades. Individuals that have insufficient comprehension and learning skills, missing or inaccurate background knowledge, or poor executive functions, are at risk to fail to learn from texts. In addition, text factors such as coherence of the text and text complexity may result in differences in learning from texts.

Individual and Developmental Differences

Comprehension skills. As a result of maturation as well as experience, reading comprehension skills undergo significant changes in childhood and adolescence. One crucial skill that improves with development is inference making (Lynch et al., 2008; Thompson & Myers, 1985). It has for example been demonstrated that 7-year-old children make more inferences in general, and more causal inferences in particular, than do 4-year-old children (Thompson & Myers, 1985). In addition, developmental changes occur in individuals' sensitivity to text structure: The ability to detect central information in the text significantly improves with age, with highly related text units being recalled, summarized, and rated as important more often in older children (Lynch et al., 2008; Trabasso et al., 1984; van den Broek, 1989b; van den Broek, Helder, & van Leijenhorst, 2013; van den Broek, Lorch, & Thurlow, 1996). Other comprehension skills that improve with age and experience are comprehension monitoring skills (Oakhill & Cain, 2012). Older children detect more inconsistencies in texts (van der Schoot, Reijntjes, & van Lieshout, 2012). In addition, older children have a larger repertoire of reading- and learning strategies (Paris, Lindauer, & Cox, 1977). Moreover, older children have more knowledge about text genres. They are better at processing difficult expository text genres such as compare-contrast and descriptive texts (Englert & Hiebert, 1984). As comprehension is an important factor in learning from text, the development of these skills and strategies will facilitate learning from texts as well.

Background knowledge. Background knowledge is an important factor in an individual's ability to learn from texts. As we described above, the relation between comprehension and learning is reciprocal and background knowledge is crucial for comprehension and learning from texts. Learning from texts may fail when background knowledge is absent, not adequately accessed, or simply inaccurate. Background knowledge develops over time, with increases in the amount of knowledge (Bjorklund, 1987; Chi, 1978; Chi, Glaser, & Rees, 1982), in the quality of knowledge (Vosniadou & Brewer, 1992, 1994), and in accessibility of knowledge (Chi, 1976). These developments in background knowledge result from formal educational activities as well as from informal learning situations. Repeated encounters with learning materials across different situations strengthen the memory trace for that knowledge and help the reader to recognize situations to which the information applies (Barnett & Ceci, 2002; Butler, Godbole, & Marsh, 2013; Gick & Holyoak, 1983). Unfortunately, the learning context is not always optimal. Sometimes students make inaccurate inferences because of limited understanding of the learned materials, miscategorization of encountered concepts, or limited understanding about what constitutes knowledge (Vosniadou, 2013). This could lead to misconceptions in memory. Misconceptions are quite common among students and even adults. They are difficult to change, particularly when they regard abstract and unobservable concepts and processes (Chi & Roscoe, 2002). Some of those misconceptions may be the result of normal development (e.g., Piaget, 1952; Vosniadou & Brewer, 1992). Children's knowledge is often based on what they have observed in the world, although many concepts can only be explained by things that are unobservable. For example, many young children believe the Earth is flat, because they *perceive* the horizon as being flat, and they reason that it needs to be flat or else people would fall off. An understanding of the shape of the Earth is only possible when the children are able to understand that some things are not what they seem to be, and when they understand the concept of gravity. Background knowledge can change without formal instruction (Vosniadou & Brewer, 1992). However, some misconceptions may continue to exist because individuals may fail to learn the accurate information due to poorly constructed learning materials or limited support from the environment.

In addition to knowledge about facts, events, and other individual units of information, background knowledge also encompasses knowledge of language to express that knowledge, in particular vocabulary. Both the quantity and quality of an individual's word representations increases through experience (Nagy, Herman, & Anderson, 1985; Richter, Isberner, Naumann, & Neeb, 2013; Verhoeven & van Leeuwe, 2008). The increase in vocabulary is particularly large in primary school, with estimates of learning 15 words a day (Hirsch, 2003). It is likely that many words are learned from texts, because texts are major sources of knowledge in schools. Conversely, the breadth and depth of an individual's vocabulary are important for learning from texts, because richer mental representations of the words foster stronger and broader activation of concepts that are associated in memory and, hence, contribute to inference making and knowledge construction (de Leeuw, Segers, & Verhoeven, 2014; C. Perfetti & Stafura, 2014; Swanborn & de Glopper, 1999).

Executive functions. Executive functions refer to a set of top-down mental processes that enable controlled goal-directed behavior, and are needed when it is not possible (or advisable) to rely on automatic processes (Diamond, 2013). Executive functions show a protracted development (Diamond, 2013; Huizinga, Dolan, & van der Molen, 2006), which may influence reading comprehension and learning from texts, particularly when strategic processes are involved. Furthermore, there is considerable evidence that individual differences in executive functions explain differences in reading comprehension (Borella, Carretti, & Pelegrina, 2010; Kieffer, Vukovic, & Berry, 2013; Locascio, Mahone, Eason, & Cutting, 2010; Sesma, Mahone, Levine, Eason, & Cutting, 2009)

and learning in general (see J. R. Best, Miller, & Jones, 2009, for a review). Highly developed executive functions help to more efficiently distribute mental resources by flexibly focusing on relevant information, ignoring irrelevant information and by monitoring and changing information that enters working memory. Given that attention is a major component of comprehension and learning, developmental and individual differences in the ability to flexibly and effectively attend to different parts of texts can explain differences in learning from texts.

Text Characteristics

Even if individuals have highly developed skills and knowledge, learning from text could fail due to text factors. Texts need to be written in a clear, coherent way so that readers can extract the message that the author wants to transfer to the reader. In general, texts that stimulate active (causal) inferential processing provide the best learning results (Gilabert et al., 2005; Linderholm et al., 2000; McNamara et al., 1996; Vidal-Abarca, Martínez, & Gilabert, 2000). Expository texts are often more difficult to read than narrative texts because of their complex and diverse structures and because students usually have less experience with these texts (R. M. Best, Rowe, Ozuru, & McNamara, 2005; Lorch, 2015). However, cues such as headers may improve comprehension and learning by directing attention to relevant information and to the structure of the presented information (Lorch, 1993; Lorch & Lorch, 1996; Lorch, Lorch, & Klusewitz, 1995). Learning from texts is most optimal when the texts match the individual characteristics of the reader. Specifically, to stimulate active processing in the reader texts need to be of adequate difficulty, matching the readers' comprehension skills and background knowledge (Britton & Gülgöz, 1991; Linderholm et al., 2000; McNamara, 2001; McNamara et al., 1996; McNamara & Kintsch, 1996; O'Reilly & McNamara, 2007).

Improving Learning from Texts

Strategy training. Learning from texts can be improved by teaching how to effectively use reading and/or learning strategies. If individuals use ineffective, superficial strategies such as skimming (i.e., glancing through the text quickly), learning is not likely to occur. There are many interventions that teach students to use effective reading comprehension strategies (for overviews see: (Duke & Pearson, 2002; Gersten, Fuchs, Williams, & Baker, 2001; Graesser, McNamara, & VanLehn, 2005; McNamara, 2007; Meyer & Poon, 2001). However, the long-term and generalization effects of those interventions often are not established (e.g., Berkeley, Scruggs, & Mastropieri, 2009; Gajria, Jitendra, Sood, & Sacks, 2007; Gersten et al., 2001). In addition, the effectiveness of learning strategies should be determined, particularly with respect to the transfer of knowledge to different situations. Such investigations would help identify effective strategies that increase learning from texts. In the context of the current theoretical framework, instruction in strategies that contribute to the construction of a coherent and strongly (inter)connected knowledge representation are most likely to prove successful.

Activation of background knowledge. Learning from texts may also be improved by providing or activating additional background information. Meaningful learning involves two phases: Encoding and retrieval. Often, information is encoded in one context, and its relevance needs to be recognized later when the information needs to be reactivated and applied in a different context. Interventions or strategies aimed at constructing knowledge representations should target both the encoding and the retrieval phase. When learners lack the required background knowledge teachers may consider providing texts or other materials that provide background information (Lipson, 1982). Interventions that target the activation of background knowledge are effective in improving comprehension (Elbro & Buch-Iversen, 2013). Also, cues could be provided that activate existing knowledge and this facilitates transfer to new situations (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980). Supplying individuals with the learning materials in varied contexts could improve decontextualization and abstraction of information that needs to be learned, making it more likely that transfer of the information will occur to different contexts (Bolger et al., 2008; Chen & Mo, 2004). Other factors that improve transfer are surface similarity of the encoding and retrieval phase, instructions focused at comparing the current problem with previously acquired knowledge, and priming a transfer mind-set (Day & Goldstone, 2012). Teachers should be careful in determining whether students lack knowledge or are unable to retrieve knowledge because these situations require different solutions. A lack of knowledge requires supplying the information to the students, whereas the inability to retrieve information requires the use of cues to retrieve the knowledge. Furthermore, students may activate inaccurate background knowledge, which could seriously interfere with learning (Lipson, 1982). Teachers should make sure to refute these misconceptions and to explain the accurate information, for example by using refutation texts (Kendeou & O'Brien, 2014; Kendeou & van den Broek, 2007; Kendeou et al., 2014).

Concluding Remarks

In this chapter, we described learning from text, focusing both on the processes and the products of learning. An important distinction was made between

learning from texts and comprehension of texts. Although comprehension is necessary for meaningful learning, it is not sufficient. Multiple encounters with the information in different texts and in different contexts and using learning strategies contribute to the gradual transition from text representations to knowledge representations. Knowledge representations differ from text representations in that they are more permanent and decontextualized. Nevertheless, text and knowledge representations influence each other in reciprocal ways -comprehension facilitates learning and knowledge facilitates comprehension- making it hard to disentangle the relations.

The research community will have to progress in two directions to gain a better understanding of learning from text. First, to fully understand the gradual transition from text representation to knowledge representation, researchers will be have to combine different measures to assess the processes that contribute to comprehension processes, learning processes, and long-term learning outcomes (knowledge representations) within a single study. Comprehension can be tested either during or directly after reading a text, with the text present. Learning outcomes however, should be tested with long-term measures because knowledge representations may change over time due to consolidation and forgetting. Consolidation is reflected in the ability to retrieve information after a delay but not immediately after the learning episode (Bauer, Evren, Starr, & Pathman, 2011). Memory may also decline after a delay, by processes of forgetting and interference. These changes in memory make immediate measures of knowledge representations unreliable predictors for future knowledge representations. Learning from text should therefore be assessed by combining short- and long-term measures.

Second, studies have to assess the extent to which learning leads to decontextualized knowledge. Whereas reading comprehension studies often assess how well information was comprehended within the context of the text, assessment of learning should also focus on how well the information can be applied to solve novel problems within a different context (Valencia & Pearson, 1987). Few studies have used questions that focus on application of information to novel situations. This is surprising, given that the aim of reading texts in educational settings is to extract knowledge that can be used in novel situations in the future. Asking the participant to apply the knowledge in novel situations, for example by having them analyze case studies, write argumentation papers, describe analogies, generate examples or solve problems, could inform about the extent to which the knowledge is decontextualized.

In addition, schools and teachers should become more aware that there are various levels of learning and that they should determine which level of learning they want their students to achieve (Bloom, 1956; Krathwohl, 2002). When the goal is to teach reading comprehension, it may suffice to assess whether the information in the text can be summarized or whether the main points can be extracted. In contrast, when the goal is to attain high-quality knowledge that can be transferred readily, teachers may need to assess application of knowledge. Thus, different target levels of learning call for different types of assessment and teaching approaches.

In this chapter we have drawn on findings from the research literature on the comprehension of texts and extended those to the context of *learning* from texts. More insights into how information is processed and how these processes may lead to the desired learning products should be targeted in future research and, and this, we hope, will inform educators to provide optimal learning context for students.