4. Constructing Mental Models during Learning from Science Text

Eye Tracking Methodology Meets Conceptual Change

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Abstract: The purpose of this chapter is to examine the process of mental model construction while reading science text. This is done by bringing together three research traditions: conceptual change, text comprehension, and eye-tracking research. The results of our experimental pilot study show the usefulness of the eye-tracking methodology in conceptual change research. This line of study can be beneficial for developing science texts and other learning materials.

Keywords: Conceptual change; eye-tracking; text comprehension.

Introduction

The aim of this chapter is twofold. First, we introduce our theoretical framework in which we integrate two theoretical research traditions: conceptual change (Limón & Mason, 2002) and text comprehension (Kintsch, 1988). Second, we introduce our pilot study that used eye-tracking to record and model the conceptual change process during learning from a text concerning photosynthesis. Eye-tracking has been widely used in cognitive psychology (Rayner, 1998), but is still new to conceptual change research.

The learning and understanding of scientific models requires reorganization of existing domain-specific knowledge structures, such as mental models. This reforming of knowledge structures is called "conceptual change" (Mason, 2001, p. 259). It seems that radical conceptual change is almost impossible to achieve without systematic instruction (Hatano & Inagaki, 1997). Thus, the importance of school teaching when inducing conceptual change in different areas is unquestionable. Despite the long research tradition (see, diSessa, 2006), initiating and supporting conceptual change in the classroom is still very challenging for learners, teachers and the designers of learning materials.

Textbooks dominate science instruction (Hynd, 2001). In everyday school practice, a large part of teaching and learning is based on different kinds of texts aiming at transmitting models about scientific phenomena, of which photosynthesis is a good example. The problem is, however, that the scientific models are often presented in textbooks as if the learners have no prior knowledge or only relevant prior knowledge about the topic to be learned; the learners' possible misconceptions are left ignored. Books seem to offer a ready-made conceptual model, and learners are assumed to understand and make effective use of the presented conceptual model although the model presented in a textbook may not fit well with existing mental models that a learner is able to activate.

This practical problem of everyday school teaching has theoretical background in, for example, Vygotsky's ideas. Vygotsky (1962) identified a gap between naïve and scientific concepts. Because naïve concepts are based on everyday experiences and scientific concepts belong to a qualitatively different conceptual system, combining of the two demands some rearrangement of the learners' existing knowledge structures. The possibility of incompatible informal mental models and new scientific conceptual models may cause difficulties for some learners. One result may be that some new scientific knowledge can remain inert and not applicable outside school in the learner's everyday life. Thus, when studying with the help of textbook texts, it is understandable that the experience of conceptual change can be extremely difficult for learners. No reorganization of knowledge structures occurs, when everyday experiences and prior knowledge do not meet with the scientific definitions of the same phenomenon.

The general theme of this edited volume is the understanding of mental models. Our theoretical target is to understand and model how young learners construct and revise mental models during science text comprehension. Furthermore, our long-term pragmatic aim is to design experimental interventions and science texts that will help young learners construct meaningful and relevant mental models appropriate for learning science. Achieving these goals will promote higher quality learning in school settings. In this chapter, we examine the conceptual change in the context of student processing information contained in science texts. We bring together research on mental models and text comprehension through the notion of conceptual change making use of an eye-tracking methodology.

Conceptual Change

Let us take photosynthesis – one of the most important concepts in the biology curriculum – as an example of conceptual change. Most children seem to have a mental model consisting of the misconception that a plant has multiple external sources of food (e.g., Hatano & Inagaki, 1997; Mason, 1994; Roth, 1990). After instruction, children are often able to show that they have learned some characteristics of the scientific model of photosynthesis on a superficial level, and they might, for example, pass a typical school test. But when children are asked to explain photosynthesis, they reveal in their explanations that they assimilate parts of the new scientific model into their naïve model (see, Vosniadou, 1994a). Children might, for instance, confuse new concepts with their old ideas; thus, they might think that plants take in sun, rain, light, soil or minerals, which then gives them energy to live. Herein lies the problem of science teaching; how to help the learners to see the differences and similarities in their own thinking and the presented scientific model, and how to make the scientific model more accessible, when the naïve model seems to have sufficient explanatory power in everyday experiences.

During recent decades, conceptual change has been studied from at least two different perspectives. Cognitive psychology has studied conceptual change as a developmental process and produced rich descriptions of the naïve theories of young learners concerning different science phenomena (Carey, 1985; Vosniadou, 1994a; Vosniadou & Brewer, 1992). Science instruction, on the other hand, has focused on the practical applications of conceptual change and developed instructional models intended to facilitate conceptual change (Posner, Strike, Hewson & Gertzog, 1982).

In conceptual change research there have been two opposing views on the nature of the learners' naïve ideas (diSessa, 2006). On the one hand, it has been argued that even very young children have domain-specific naïve, theory-like mental models about scientific phenomena. These models are constructed in everyday interactions and used when everyday events need to be understood and predicted (see, e.g., Vosniadou, 1994a). Vosniadou (1994a) argues that conceptual structures can be altered either by adding more information to them (so-called *enrichment*) or by replacing old conceptions with new ones (so-called *revision*). On the other hand, prior knowledge may consist of fragmented elements. These elements can be used in forming coherent, scientific models (diSessa, 2006). According to this view, as Smith, diSessa and Roschelle (1993) and Siegler (1996) argue conceptual change is not a sudden but more of a gradual process; it is *evolutionary* rather than *revolutionary* (Sinatra, 2002, p. 190). Still, all theories of conceptual change agree that conceptual change can happen on more than one level (Duit & Treagust, 2003; White, 1994).

Piaget's (1950, 1985; see, Schnotz & Preuss, 1997; Vosniadou, 1994b) theory of intellectual development includes the concept of *cognitive equilibrium*. The cognitive system tries to avoid conflict between newly presented information and already existing knowledge. Cognitive equilibrium has later on been used to explain routes to conceptual change. Hence, when a conflict occurs, the attempt to restore cognitive equilibrium may lead to conceptual change. Hewson (1981) and Posner and colleagues (1982) consider this so-called *cognitive conflict* to be a necessity in experiencing conceptual change. According to them, one has to be discontented with one's old conceptions before they can be altered. In the light of new experiences, old conceptions are no longer sufficient; thus, there is a conflict between existing knowledge and new information. Accepting new information requires that it is considered intelligible, plausible and/or fruitful (Posner et al., 1982).

Both cognitive psychologists and science instructors consider the inducing of cognitive conflict to be an important element of conceptual change (Guzzetti, Snyder, Glass & Gamas, 1993; Kang, Scharmann & Noh, 2004). Nonetheless, producing cognitive disequilibrium does not always result in desired conceptual change; what will surely result is an attempt to achieve cognitive equilibrium, but this may involve an undesired conceptual change. One can also try to achieve cognitive equilibrium by forming new erroneous theories or by creating synthetic models where there are elements from both naïve and scientific models. (Vosniadou, 1994b). Thus, merely producing cognitive conflict is not sufficient when aiming for a particular conceptual change. It has been suggested that motivational factors may also account for lack of success in resolving cognitive conflict to promote learning (Olkinuora & Salonen, 1992). According to studies conducted by Kang and colleagues (2004), cognitive conflict can be one of the important factors of conceptual change, but it is not a necessary precondition.

The theory by Posner and colleagues (1982) requires that one is conscious of the nature of ones thinking; only after that can different conceptions be compared to each other and there are grounds for experiencing cognitive conflict and conceptual change. This awareness of the theoretical nature of ones thinking is called *metaconceptual awareness* (Vosniadou, 1994a). According to conceptual change research this seems to be a necessary, though not sufficient, precondition for conceptual change. In order to change something, one has to both realize the need for it and be willing to do so (Limón, 2001, p. 359; White & Gunstone, 1989).

Mental Models and Text Comprehension

A common notion about text comprehension is that a reader constructs mental representations during text processing. For instance, Kintsch and van Dijk (1978) assumed in their earliest model that the meaning of a text could be parsed into semantic units, so-called *propositions*, which are interconnected according to coherence relationships. Comprehension was perceived adding together semantic units. Inferences were seen to have the function of bridging coherence gaps within the text. With this model, it is possible to model the process of text comprehension adequately to some extent, but only as long as no misunderstanding occurs and the reader is not forced to reinterpret what has read before (Mandl & Schnotz, 1987).

In contrast to this additive-elementaristic view, the later models of text comprehension attempted to describe text comprehension with the help of holistic structures (Johnson-Laird, 1980, 1983; van Dijk & Kintsch, 1983). For instance, van Dijk and Kintsch (1983) modified and extended their earlier model into the so-called *Construction-Integration (CI)* model (Kintsch, 1988; see also Kintsch, 1986, van Dijk & Kintsch, 1983). According to the CI model, the process of text comprehension proceeds in a two-phased cycle. In the *construction* phase, propositions activate in the reader's mind a network of related concepts. This network consists of both relevant and irrelevant concepts. In the next phase, *integration*, this network is established; new propositions that are consistent with the reader's prior knowledge are left active and inapplicabilities are discarded. (Kintsch, 1988.)

In the CI model, there is a distinction between two types of representations built while reading the text (Kintsch, 1988). The *text base* is constructed from propositions and expresses the semantic content of the text at both local and global level. The *situation model*, on the other hand, is the mental representation of the situation described by the text (Kintsch 1986). The situation model may be, for example, the readers' mental map of a town described in the text, an arithmetic structure derived from the text, or, as in our studies, a scientific model of photosynthesis constructed from the content given in the text. These two representations, the text base and the situation model, are not independent of each other, but each has its own characteristics and each supports certain types of learning. (Kintsch, 1986.)

Although these theoretical concepts are all hypothetical, there is empirical evidence for the dichotomy of the text base and the situation model. Kintsch (1986) draws the pedagogical conclusion that if the learner has constructed a text base during reading, the learner can remember the text itself; however, understanding the content of the text demands the construction of a correct situation model. Thus, there is a difference between learning *the* text and learning *from the* text. Also Johnson-Laird (1980, 1983) assumes that in reading the text, besides the propositional representation of the text a mental model is constructed. The mental model is a holistic structure representing the content in a directly analogous manner instead of an indirect digital manner. In text comprehension, mental models are constructed on the basis of propositional representation and of prior knowledge. Thus, comprehension of a text may go beyond the immediate content of the text, and so the text itself loses its individuality, and its information content is integrated into some larger structure as Kintsch (1988) has proposed.

Despite the fundamental dichotomy of the two mental representations in the presented theories, later on it was argued that the reader forms one mental model instead of two separate ones while reading, and this mental model can be observed from two dimensions; the text base and the situation model as presented above (McNamara, Kintsch, Butler Songer & Kintsch, 1996). Thus, these approaches by van Dijk and Kintsch (1983) and Johnson-Laird (1980, 1983) may be called holistic since they assume that from the very beginning of the comprehension process a holistic mental structure or mental model is constructed, evaluated and eventually revised on the basis of the text and prior knowledge. Hence, mental inferences are perceived as less text- dependent in that they also not only serve to fill the coherence gaps in the text but are used to enrich and elaborate the mental model of the learner. Inferences function at the conceptual level rather than the linguistic level (Kintsch, 1986; Mandl & Schnotz, 1987).

One of the most important factors in text processing is the reader's working memory (Kintsch & van Dijk, 1978). The concept of *cognitive overload* is closely related to working memory (Armand, 2001; Sweller, 1994). Cognitive overload occurs when the reader's working memory capacity is not sufficient for the comprehension task, and thus the processing of text becomes much of a strain. When the reader has low prior knowledge, a coherent text might lessen the cognitive load and the effective processing of the contents could succeed.

Text processing is also influenced by text coherence. A coherent text facilitates the remembering of details and the forming of a knowledge structure. (McNamara et al., 1996). When, for example, the reader has low prior knowledge of the presented subject, the text should be coherent enough so that the reader's working memory is not overloaded. On the other hand, high prior knowledge readers have been found to benefit from a text with low coherence, because this forces them to process more actively during reading (Schnotz, 1993). Thus, the results are contradictory. In general, it can be stated that a text that increases mental activity during reading, will benefit all readers irrespective of the level of prior knowledge (Gilabert, Martinez & Vidal-Abarca, 2005).

Thus, it seems that both the reader with his/her personal characteristics and the text influence the process of text comprehension. The reader's prior knowledge of the text's subject has an impact on the understanding of what is being read, and thus on the experience of conceptual change. Apart from this, text comprehension can also be influenced by text coherence.

Eye-tracking Research

Previous studies have demonstrated the connection between the reader's focus of attention and eye movements while reading (Hyönä, 1998). The reading process can be examined extremely accurately with eye-tracking methodology. Hence, the reader's cognitive processes during reading can be inferred on the basis of the reader's eye movements. Previously, the studies on eye tracking have focused mainly on the recognition of words or syllables, but according to Hyönä, Lorch and Rinck (2003), this methodology can also be beneficial when text processing is studied on a macro level.

The reading process is not continuous but consists of short stops, *fixations*, and the transitions from one fixation to another, so-called *saccades*. An adult reader's length of fixations during reading varies from 200 to 300 milliseconds, whereas the saccades are remarkably shorter (Rayner, 1998). It is commonly admitted that the reader acquires information only during fixations (e.g., Kaakinen, Bertram & Hyönä, 2004).

Problems during reading can be caused either by difficulties in word or letter recognition, or in understanding the contents of the text. *Regression* is often considered to be a symptom of problems in the reading process. Hyönä, Kaakinen and Lorch (2002) argue that fixations moving forward and regressions inside a sentence refer more to mechanical reading skills. According to them, eye movements in a wider range, in and out of sentences can indicate problems in understanding the content. (Hyönä et al., 2002). Nevertheless, if the reader experiences difficulties in text comprehension, returning to the previous text is not the only solution to the problem. The reader might continue his/her reading and expect the following text to clarify the part s/he did not understand. Naturally, the reader can also rely on his/her working memory and solve problems of understanding without showing it in the reading process at all. Thus, situations where problems of understanding the contents of the text occur are not always visible. (Hyönä et al., 2003).

Regression in text processing can be observed from two different perspectives; from the target of re-reading or from its starting point. When the reader goes back to a certain part of text and re-reads it that text unit collects what are called *look backs*. Look backs might occur when the reader needs to return to a critical text unit, a unit that caused cognitive difficulties and had content that needed to be clarified. On the other hand, there is always a starting point – e.g., a word or a sentence – for the returnings to previous text. When the reader leaves a text unit to read previous text again, this text unit collects so-called *look froms*. In this way, the critical text unit can be seen as the one that is evoking text processing immediately when cognitive difficulties with text comprehension occur. When look backs and look froms are studied, the observer actually tracks down fixations that have landed on a certain area. The role of a fixation is defined on the basis of the directions of the surrounding saccades (see, Hyönä et al., 2002).

Look back time describes the amount of time spent on re-reading a critical text unit. Look back time is the sum of all fixations that land on a part of text after its first reading (Hyönä et al., 2003). *Look from time* consists of the fixations that land on previous text in the middle of reading the critical text unit (Anto & Penttinen 2006; Hyönä et al., 2002). Look from time starts when the reader leaves an unfinished sentence and ends when the reader returns to the sentence and reads on. A longer look from time can be seen as longer look back times in the sentences to which the reader returns. The concepts describe problem solving in reading process from two perspectives; look froms and look from time tell us where the reader started to process the text, while look backs and look back time describe where the reader returned. Nonetheless, the concepts look from time and look back time are not exactly mirror images, since the look from time of a sentence can be divided into look back times for several sentences.

The concepts used in eye-tracking research still lack unity, though there have been attempts to simplify the terminology (Hyönä et al., 2003). Here we present some variables that can be examined in the reading process.[5] *Total fixation time* describes the time used in reading the text. The reading process can be examined more closely with such variables as *regression path duration* and *selective regression path duration*. The regression path duration of a sentence includes all fixations during the reading of a particular sentence. Thus, it also includes those fixations that land on previous text, i.e., look backs, besides the sentence in question. The selective regression path duration of a sentence only includes those fixations that land on the sentence itself. Thus, selective regression path duration can be

[5] The variables and their definitions are based on the software (DataViewer) used in the experimental study that will be presented later in this chapter.

counted by deducting from regression path duration the fixations that land on previous text, that is, look from time.

Ways of solving cognitive difficulties during reading: (Hyönä et al. 2003)	**Indicators used in eye-tracking research:**
Slow reading	Fixation time
Instant re-reading of the critical part of text	Selective regression path duration
Reading on	Linear reading
Reading on and *turning back to the critical part* of text	Look back time
Returning to previous text *from the critical part* of text	Look from time

Experiencing Cognitive Conflict while Reading Science Text

We believe that combining conceptual change research with theories on text comprehension can bring us nearer to the process of conceptual change. When defining conceptual change in text comprehension process through the CI model, conceptual change can be seen as rearranging and supplementing the knowledge network. One of the possible paths to conceptual change, cognitive conflict (i.e., the possible mismatch between prior knowledge and the scientific models to be learned from the text), can most likely be experienced at different levels of comprehension. On a propositional level, cognitive conflict can be placed between a newly faced, naively interpreted proposition and the more or less scientific-like text base (Mikkilä-Erdmann, Anto, & Penttinen, 2006).

If naïve misconceptions dominate the text comprehension process, parsing a new proposition might activate units in the reader's knowledge network that are false when compared with the scientific information presented in the text. Cognitive conflict or conceptual change cannot occur, since the text comprehension process is misguided at an early phase. Misconceptions can in some cases lead the process of understanding in that the scientific-like conceptions are left ignored, or the reader adapts some scientific elements to his/her naïve theory and creates a so-called synthetic model (see, Mikkilä-Erdmann, 2002; Vosniadou, 1994a). In order to make the experiencing of cognitive conflict in the text comprehension process possible, the reader must be able to give up interpreting propositions using only naïve misconceptions and build the situation model through the information offered by the text instead. This requires a conscious guiding of the text comprehension process, and also favorable motivational-emotional circumstances.

Prior knowledge is an important factor both in text comprehension (Armand, 2001) and conceptual change (Mayer, 2002). Previous studies have proved that while studying from a text, activating the reader's prior knowledge and making the reader aware of the differences between naïve conceptions and the scientific model – that is, inducing cognitive conflict and awakening metaconceptual awareness – will benefit comprehension (Alvermann & Hague, 1989; Hynd, 2001; Hynd & Alvermann, 1986). According to a commentary of conceptual change theories by Mayer (2002), prior knowledge can both hinder conceptual change and create the conditions for it by working as building blocks when constructing new models. Also Alvermann and Hague (1989) argue that merely activating prior knowledge is not enough, since it can hinder the acceptance of the scientific model.

The effects of these so-called *refutational texts* on learning outcomes have been studied during the last couple of decades. In their studies, Alvermann and Hague (1989) used an introductory text passage where readers were warned about the possible inconsistencies between naïve and scientific models. This was done to awake the reader's awareness of his/her own thoughts on the subject. Mikkilä-Erdmann (2002), on the other hand, created a text with *metaconceptual text units* that were embedded within the text. These units were designed to support the reader's metaconceptual awareness by challenging his/her possible misconceptions and again inducing cognitive conflict by pointing out the differences with scientific models. In eye-tracking research the strong effect of *reading perspective* on the reading process has been confirmed (Kaakinen, 2004). It is suggested here that activated metaconceptual awareness could work the same way than reading perspective. Metaconceptual awareness could guide the reader to form the text base by constructing propositions according to the text and not only according to the readers' misconceptions. (Mikkilä-Erdmann et al., 2006.) Hence, the result would be a coherent, meaningful and complemented scientific mental model, and the reader would have solved the problem of cognitive equilibrium so that it leads to conceptual change.

The problem with earlier studies on inducing conceptual change through text has been that the focus has been mainly on the learning outcomes, whereas the process itself has been left unexplored. This has been mostly due to the limitations of the used methodologies. In this chapter, the problems of constructing mental models in text comprehension process will be examined with eye-tracking research methodology. This methodology offers the possibility to observe the reading process more closely.

When tracing cognitive conflict in text comprehension process, the critical moment is when a reader has problems constructing either the text base or the situation model. Problems on the text base level can occur when, for example, naively interpreted conceptions do not fit in the more or less scientific-like text base. When forming the situation model, the reader might have difficulties if new information contradicts with the reader's prior knowledge. According to van Dijk and Kintsch (1983), while constructing the text base, the reader has to compare a new proposition to the already formed text base. This can be done by relying on working memory or, if this is not enough, by re-reading previous text for support. The term presented in this chapter, look from time, describes this returning to previous text precisely when the problem occurs. Solving difficulties experienced when forming a situation model, on the other hand, could demand different strategies, such as returning to the critical text unit after reading on. Thus, it is argued here that look from time would be beneficial when observing the text processing more on a text base level, and look back time might be better in observing the cognitive problems occurring during the formation of the situation model.

Experimental Study

The target of our research project is to model cognitive processes such as experiencing cognitive conflict during science text comprehension. We are conducting experiments with the aim of making the process of conceptual change visible. Furthermore, we are investigating instructional tools, such as texts, that could facilitate conceptual change in classroom situations. We present the pilot study of this research stream next.

Research Objectives and Method

The target of the experimental study presented here was to find out if cognitive conflict experienced during text processing can be traced using eye movement research methodology (Anto & Penttinen, 2006; Anto, Penttinen, & Mikkilä-Erdmann, 2007). Based on earlier findings, the hypothesis was that the experience of cognitive conflict in the reading process might cause more text processing. In this study, such variables as *total fixation time, selective regression path duration* and *look from time* were examined in each participant's reading process. The other goal of this study was to examine the effect of text type on inducing cognitive conflict. The eye-movement methodology was used to examine the reading processes of two different text types.

Thirty sixth-graders participated in this study. The participants were randomly divided into two treatment groups. In a laboratory setting, the participants read a science text concerning photosynthesis and did some written exercises. Written pre- and delayed posttests were used to identify changes in the participants' conceptions on photosynthesis. The pre- and delayed posttests were identical and were carried out in the participants' own classrooms.

Two different treatment texts were used. The *refutational text* was based on Mikkilä-Erdmann's (2002) studies about children's naïve conceptions of photosynthesis. The text included so-called metaconceptual text units, which were planned to both activate the readers' metaconceptual awareness and point out the possible differences between the readers' misconceptions and the scientific model (e.g., "It's important to understand that a plant does not take ready-made food from the soil and therefore it does not eat."). Metaconceptual text units were assumed to cause more text processing, and help when experiencing cognitive conflict. The *explanatory text* was otherwise identical to the refutational text but the metaconceptual text units were replaced with other sentences. The refutational text was slightly longer than the explanatory text (2540 vs. 2369 letters and punctuations marks), due to the necessary added words in the metaconceptual text units.

In a laboratory setting every participant read two texts on a computer screen. Reading processes were recorded using EyeLink II (SR Research Ltd., Toronto, Ontario, Canada). First, all participants read a control text on a related subject. The purpose was to make the participants familiar with the head-mounted eye-tracking camera. After that, every participant read the treatment text. The length of time allowed for reading the texts was not limited.

The reading processes were examined both on the word and sentence level through multiple variables. Based on the theoretical background and the preliminary analysis, some variables were chosen for a more accurate analysis. *Total fixation time* and *selective regression path duration* were converted into milliseconds per sign. Letters and punctuation marks were counted as signs. *Look from time* was converted into milliseconds per sentence, since the whole sentence was considered to enable the possible processing, while the length of the sentence was of no importance. The eye-movement data were analysed by DataViewer.

The written pre- and delayed posttests consisted of text-based *fact finding* (e.g., "What are stomata?") (see, van Dijk & Kintsch, 1983) and so-called *generative questions* (e.g., "Do a carrot and a rabbit get energy the same way?") (see, Vosniadou, 1994a). Correct answers to the latter demanded a scientific mental model on photosynthesis. The scales for rating the written answers were formed on the basis of the participants' answers. Thus, the questions were rated either from 0 to 3 or from 0 to 4. The maximum score always demanded a scientific answer. The interrater reliability was 87.6%. Due to the two different scales, the ratings were changed into percentages, the maximum score (3 or 4) being 100%.

Results

The two treatment groups (n=15/group) were found comparable when the participants' scores in the pretest, the grade in science, the GPA of theoretical subjects, and the total fixation time in reading the control text were examined using the independent samples T-test. Because of unsuccessful eye-tracking data five participants (2 refutational text and 3 explanatory text readers) had to be excluded.

The effect of text type on the change of scores in generative questions and the reading process was tested with the repeated-measures ANOVA. No significant interaction effect was found. The two treatment groups were then combined for the following analysis.

The participants' level of conceptual change was defined on the basis of the performance in generative questions from pretest to delayed posttest. The participants were divided into three groups. Group 1 showed either no change in their scores or even occasional regression, and thus its members did not experience a change in their conceptions about photosynthesis. Group 2 slightly improved their scores from pretest to delayed posttest, the maximum improvement being 13.33%. Thus, for the members of group 2, some elements of photosynthesis were more scientific-like after this intervention, but no conceptual change as such occurred. Group 3 improved their scores by at least 20%, and were seen to have experienced conceptual change to some extent.

The reading process of the treatment text was compared in relation to the participants' level of conceptual change. An independent samples T-test was conducted to compare the reading processes of groups 1 and 3, the no conceptual change and conceptual change groups. Group 2 did not fulfill the null hypothesis of the normal distribution and was thus left out of the following analysis.

Table 1. Means and standard deviation of groups 1 and 3 for total fixation time, selective regression path duration and look from time

Groups	N	Total fixation time *(ms/sign)* M/SD	Selective regression path duration *(ms/sign)* M/SD	Look from time *(ms/sentence)* M/SD
1 no conceptual change	12	63,8/15,8	61,9/14,8	142,6/102,6
3 conceptual change	4	75,5/17,9	68,7/15,0	432,3/223,4

Total fixation time (ms/sign) was slightly longer for those who experienced conceptual change to some extent, although the difference is not significant, t(14)= –1,248; p> 0,05 (see, table 1). Selective regression path duration (ms/sign) is slightly longer for the conceptual change group, but the difference is not significant, t(14)= –0,794; p> 0,05. The most important finding was that look from time (ms/sentence) was significantly longer for the conceptual change than the no conceptual change group, t(14)= –3,644; p< 0,01. The results suggest that those readers who experienced conceptual change spent more time in re-reading previous text than the readers who did not experience conceptual change. Thus, it seems that look from time may work as an indicator of cognitive conflict in science text processing.

General Discussion

The theoretical aim of this chapter is to combine two research traditions, conceptual change and text comprehension. This is done in order to investigate how learners experience conceptual change during learning from science text. Both research traditions deal with cognitive processes, which are not visible or easily observable, and are mostly examined on the basis of performance measurement from pretest to posttest. Thus, the results of different interventions are well documented, but the process of conceptual change (or not succeeding in it) has been left unexplored.

On the basis of our explorative study, we consider eye-tracking an appropriate method for examining conceptual change processes during text comprehension due to its long research tradition in examining cognitive processes, and its extremely accurate online results. Although eye tracking gives us new possibilities for investigating cognitive processes online, this is not enough when examining the construction of mental models. A multi-method approach seems necessary; for example, the think aloud method, stimulated recall interviews etc. could complete and validate the research design. Nevertheless, on the basis of our explorative study we found possible indicators of cognitive conflict in the reading process, and progressed a little in the analysis of the conceptual change process during text comprehension. There are still many challenges – both theoretical and methodological – that have to be dealt with in future studies.

The importance of well-written texts as one component of school teaching is unquestionable. Thus, studies on both the texts and the ways they are studied are extremely relevant, when trying to help learners to achieve a true understanding of difficult concepts. In their studies, Hyönä et al. (2002) categorized four reading strategies[6], which differ in, for example, the time used for reading and the way the text (headlines, beginnings of paragraphs etc.) is processed. The ability to write summaries after reading a text varies between different strategies; those who processed the text systematically produced the best summaries. (Hyönä et al., 2002). These personal ways of processing a text bring a new perspective to our studies on conceptual change in text comprehension. The role and stability of reading strategies have yet to be examined more closely. They also need to be compared to the possibilities to affect the reading process by building the text in a way that would promote beneficial reading strategies, enabling a better understanding of the subject, and thus create a good basis for experiencing conceptual change. In addition to the reading strategies, the reading perspective already discussed in this chapter

[6] The strategies are named as fast linear readers, nonselective reviewers, slow linear readers and topic structure processors (Hyönä et al., 2002).

(e.g., Kaakinen, 2002) offers interesting possibilities when trying to induce conceptual change in the text comprehension process.

As mentioned above, textbook texts still need to be investigated and developed further. This is also one of the most important applications of our line of study. The development of the refutational text design must be continued and tested with larger samples. For a learner, the awareness of a cognitive conflict is an important factor in promoting conceptual change. Our future task is to reflect on the question whether it is possible to provide the readers with more effective metaconceptual monitoring through text design. Hence, we have to develop and test a text that would lead the learner from enrichment to revision of mental models by supporting the readers' metaconceptual awareness. Later on, relevant pictures and other learning materials (e.g., multimedia learning environments) will be added to the created text design and their interaction will be studied.

However, in order to promote radical conceptual change at school, a textbook text and integrated pictures are not enough. The whole instructional process should be planned so that it supports conceptual change (Vosniadou & Ioannides, 1998). The main idea would be to design the whole instructional environment so that it would be possible to make the misconceptions visible to the learners and teachers. This would suggest a knowledge-building community in which learners would have the possibility to become aware of their prior knowledge in discussions and collaborative learning settings (Chann, Burtis & Bereiter, 1997). The role of text in a knowledge-building community or in problem-based learning has been left unexplored. Texts are already used as tools, though much more information on the text comprehension process is needed.

As Seel (2004) sums up, in a learning situation, besides the learner's preconceptions, also his/her motivation towards the task has to be taken into consideration. There has been criticism of conceptual change research being too "cold" and not taking learners' motivational-emotional factors into account (Sinatra & Mason, 2007; Sinatra & Pintrich, 2003). It has been suggested that the students' motivation, the way they approach a learning task, also plays an important role in experiencing conceptual change (Hynd, Holschuh & Sherrie, 2000). There is a research tradition on *motivational orientations*, which has shown that, at school, the learners perform in very different ways depending on their orientations (Olkinuora & Salonen, 1992). Motivational orientations seem to be related to the responsiveness or resistance to conceptual change; the orientations of the learners will either lend support or function as a filter in the conceptual change process (Mikkilä-Erdmann & Lepola, 2004). Hence, our global target would be to design instructional interventions which not only try to promote conceptual change but also foster task orientation. The motivational factors of the learning situation also have to be taken into consideration, when planning the way to present the learning task to the learner. The complex process of learning has to be studied as a whole, since no text or any other single factor of school teaching alone can produce the best outcomes.

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