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The effects of activating prior topic and metacognitive knowledge on text comprehension

scores

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Abstract

Background. Research on prior knowledge activation has consistently shown that activating learners' prior knowledge has beneficial effects on learning. If learners activate their prior knowledge, this activated knowledge serves as a framework for establishing relationships between the knowledge they already possess and new information provided to them. Thus far, prior knowledge activation has dealt primarily with topic knowledge in specific domains. Students, however, likely also possess at least some metacognitive knowledge useful in those domains, which, when activated, should aid in the deployment of helpful strategies during reading.

Aims. In this study, we investigated the effects of both prior topic knowledge activation and prior metacognitive knowledge activation on text-comprehension scores.

Samples & Methods. Eighty-eight students in primary education were randomly distributed amongst the conditions of the 2 x 2 (prior topic knowledge activation yes/no x prior metacognitive knowledge activation yes/no) designed experiment.

Results. Results show that activating prior metacognitive knowledge had a beneficial effect on text comprehension, whereas activating prior topic knowledge, after correcting for the amount of prior knowledge, did not.

Conclusions. Most studies deal with explicit instruction of metacognitive knowledge, but our results show that this may not be necessary, specifically in the case of students who already have some metacognitive knowledge. However, existing metacognitive knowledge needs to be activated in order for students to make better use of this knowledge.

Keywords: Text comprehension, prior knowledge activation, metacognition.

Introduction

Being able to understand a printed passage forms the basis for learning in many academic subjects. If students are to perform well at tasks that require reading, they need to be able to comprehend what they are reading (Law, Chan, & Sachs, 2008; Savolainen, Ahonen, Aro, Tolvanen, & Holopainen, 2008; Spörer, Brunstein, & Kieschke, 2009). However, text comprehension is often difficult for students, particularly if they do not make use of what they already know, that is, utilize their prior knowledge. Whereas most research on prior knowledge has shown beneficial effects of prior knowledge activation, this has mainly focused on topic knowledge. Here we also focus on the activation of prior *meta*cognitive knowledge.

Prior knowledge

People's prior knowledge about a topic of a passage influences what they remember (e.g., Amadieu, Van Gog, Paas, Tricot, & Mariné, 2009; Chi, de Leeuw, Chiu, & Lavancher, 1994; De Grave, Schmidt, & Boshuizen, 2001; Ozuru, Dempsey, & McNamara, 2009). Prior knowledge improves memory for new information (Pressley & Hilden, 2006) and does so in several different ways: 1) improved coding, that is, being able to store new information in larger chunks rather than separate elements, 2) useful associations, that is, having stronger connections between information elements, and 3) decision making, that is, being able to tell which are or aren't useful approaches.

The available knowledge should be actively used during information processes in order to establish relationships between the knowledge that is already available and new information provided to learners (Mayer, 1979). Prior knowledge is not automatically present in working memory, and readers have to bring their prior knowledge from long-

term memory into working memory, that is, activate their prior knowledge, in order to process that information. Because new information is better integrated with existing information, recall for information is superior compared to when prior knowledge was not available (Mayer, 1979).

However, readers often don't activate their prior knowledge automatically. Facilitating prior knowledge activation has been shown to have a strong positive impact on learning (see Mayer, 2003 for an overview; Alvermann, Smith, & Readance, 1985). A well-known technique for activating prior knowledge is mobilization, where leaners are encouraged to bring to mind items of a certain category, and each activated item tends to activate similar items (Peeck, van den Bosch, & Kreupeling, 1982). Mobilization can be seen as a bottom-up oriented strategy and serves as a broad framework that can be used to integrate new information (Kintsch, 1988; Peeck et al., 1982). Machiels-Bongaerts, Schmidt, and Boshuizen (1995) showed that mobilizing specific knowledge such as U.S. states, presidents or fishery law resulted in higher recall for items in the mobilization categories and not for other items. Mobilization enables learners to bridge the gap between their prior knowledge and new information provided to them with beneficial effects on learning, and furthermore seems particularly effective for learners with low levels of prior knowledge. Learners with more prior topic knowledge seem to benefit more from other methods of prior knowledge activation, such as perspective taking (Wetzels, Kester, & Van Merriënboer, 2011). In perspective taking, learners are asked to take a certain perspective, such as reading a text from the perspective from a home-buyer or a burglar (Pichert & Anderson, 1977), thereby creating a specific context for learning and enhanced recollection of the information fitting with the perspective.

Metacognitive Knowledge

Thus far, prior knowledge activation has been used as a strategy aimed at facilitating the linkage of new information and existing knowledge by focusing on the topic knowledge within schemas. However, learners may not only have topic knowledge of a domain; with the focus on reading strategies in education, students are likely to also have metacognitive knowledge that can be useful when reading a text (Pintrich, 2002), as it allows student to process texts more strategically.

A typical characteristic of good readers is that they use learning strategies to enhance learning. Learning strategies facilitate learning, enhance performance, and are essential for academic development. Alexander, Graham and Harris (1998) characterized learning strategies as purposeful, in the sense that a person applies them deliberately to attain a desired outcome. For students to decide when they need to deploy learning strategies, they need sufficient metacognitive knowledge. Flavell (1979) defines metacognitive knowledge as the knowledge or beliefs of what variables act and interact in ways to affect the course and outcome of cognitive enterprises. Metacognitive knowledge comprises knowledge on *how*, *when* and *why* to use learning strategies (Schraw & Dennisson, 1994). This type of knowledge is a prerequisite for independent use of learning strategies; if students are unable to call upon metacognitive knowledge, they are unlikely to deal effectively with difficult situations that may have been alleviated through strategy use.

Students who lack metacognitive knowledge suffer from an availability deficiency, thereby not having sufficient metacognitive knowledge to deal with the problem at hand (Winne, 1996). For these students, strategy instruction needs to

explicitly address the missing metacognitive knowledge and the effectiveness of teaching metacognitive knowledge has been readily established. For example, meta-analyses have shown moderate effect sizes of interventions related to metacognitive knowledge on performance scores (Dignath, Büttner, & Langfeldt, 2008; Donker, De Boer, Kostons, Dignath van Ewijk, & Van der Werf, 2014).

However, students may already possess some metacognitive knowledge, but may not effectively utilize this knowledge, which is known as a production deficiency. Thus far, countering such production deficiencies have involved presenting students with external cues during the learning task to stimulate metacognitive skill use (Jacobse & Harskamp, 2009; Veenman, Van Hout-Wolters, & Afflerbach, 2006). However, another explanation might be that students do indeed possess at least some meta-cognitive knowledge, but this knowledge has not been brought into working memory. Just as with prior topic knowledge activation, using and improving metacognitive knowledge present in long-term memory likely requires activation of this knowledge and if metacognitive knowledge is not activated beforehand, it may be less likely that students will use what they know during the learning task, leading to inferior text comprehension.

The current study

While positive effects of prior topic knowledge activation have been established in a multitude of studies, the effects of activating prior metacognitive knowledge on performance have not, to our knowledge, been investigated. In this study, we investigate the effects of both stimulating students to activate their prior topic knowledge and their prior metacognitive knowledge on their text comprehension through a 2 x 2 design, with the question whether a) students who activate prior topic knowledge outperform those

who did not, which we expect to be so, b) students who activate prior metacognitive knowledge outperform those who did not, which we expect to be so, and c) there is an interaction effect between both interventions, which is an open question. We expect that participants engaging in prior topic knowledge activation (Hypothesis 1) or prior metacognitive knowledge activation (Hypothesis 2) would outperform the control condition. Which of the two ways of activation proved to be most effective, was an open question (Question 3). For prior knowledge, we chose a mobilization method, as this has proven to be a suitable way of activation prior knowledge in domains in which learners do not have much experience yet.

Method

Participants

Eighty-eight Dutch primary education students (age $M = 11.39$, $SD = .70$) from one school voluntarily participated in this research. These students were all from grade 5, chosen because their teachers indicated that these students had had the most experience with metacognitive activities, but were also likely to benefit most from trying to activate their metacognitive knowledge. Forty-four participants were female, 44 were male. They were all native Dutch speakers.

Design

A 2 x 2 experimental design was implemented in this experiment, with Prior Metacognitive Knowledge Activation (P*M*KA; yes/no) and Prior Topic Knowledge Activation (P*T*KA; yes/no) as factors. Participants were randomly distributed over the conditions.

<Insert Table 1 here>

Materials

Texts. One single text on the topic of thermal energy was split into two texts. The first text was a description of the concept of thermal energy, and was 692 words long. The second text concerned the application of thermal energy and was 754 words long.

The text was chosen because it was very unlikely that participants had much experience with the topic. Even if they had had any experience with the subject, this would show at the pre-test, when students had read half the text (e.g., if performance at the pretest had been very high, the experiment would have been repeated with a different text).

Pre- and posttests. Each text was followed by eight multiple choice questions (see Appendix 1 for example items) with four response options each about the text. Cronbach's alpha's for the pre- and post-test were .68 and .64 respectively.

Strategy questionnaire. General strategy use by participants was measured by presenting them with twelve items (see Appendix 2) to which they could either answer (a) usually do not do this (0 points), (b) do this sometimes (1 point), or (c) usually do this (2 points). Scores on these items were added together, leading to a sum score between zero and 24. The reliability of this questionnaire was sufficient (Cronbach's alpha = .71)

PTKA. Prior topic knowledge activation was achieved by providing the title of the previous text and asking participants to write down in keywords what they remembered from that first text (i.e. "Last week, you read a text on the topic of Thermal Energy. Before reading more on this subject, please write down as many words you can remember from that text."). Participants were told not to focus on words such as "or" or "the", but on words that were important for understanding that specific text.

PMKA. Prior metacognitive knowledge activation was achieved by providing the title of the previous text and having participants write down in keywords what strategies they had used while reading the first text (i.e., "Last week, you read a text on the topic of Thermal Energy. Before reading more on this subject, please write down which strategies you used while reading that text."

Procedure

At the start of the first session, participants received the strategy questionnaire. When all participants had finished this questionnaire, they read the first text in half an hour, then had ten minutes to answer the eight questions (considered the pre-test). After this first session, participants were randomly assigned to the four conditions.

A week after the first session, participants took part in the second session. Participants in the control condition were asked to read the second text, again in half-an-hour, and then had ten minutes to answer the post-test. Participants who had to activate only prior topic or metacognitive knowledge, received five minutes to do so before being handed the text, subsequently proceeding as the participants in the control condition. Participants who did both activations, were asked to activate their metacognitive knowledge first and topic knowledge second before proceeding to the second text.

<div align="center">

Results

</div>

Correlations

The score on the pre-test was positively correlated with the scores on the post-test ($N = 88$, $r = .318$, $p = .003$). For participants who had to activate their prior topic knowledge ($n = 44$, $M = 3.91$, $SD = 1.14$)), activated prior topic knowledge as determined by the number of correct keywords was positively correlated with the score on the post-

test after the second text ($r = .338$, $p = .028$), but not with the pre-test ($r = -.021$, $p =$ .893).

For participants who had to activate their prior metacognitive knowledge ($n = 44$, $M = 2.00$, $SD = 1.26$)), the level of metacognitive knowledge was positively correlated with the number of strategies that were activated ($r = .497$, $p = .001$).

The level of strategy knowledge of all students, as determined by the strategy questionnaire, seemed to correlate negatively with the post-test score, but this correlation was not significant ($N = 88$, $r = -.18$, $p = .10$). The number of strategies activated as determined by the number of strategy-keywords written down was also negatively correlated with the post-test ($n = 44$, $r = -.265$), but this correlation was non-significant ($p = .082$)

ANOVA

Significance levels were set at .05. Partial eta squared (η_p^2) is reported as a measure of effect size, with 0.01, 0.06, and 0.16 corresponding to small, medium, and large effect sizes, respectively (see Cohen, 1988).

Table 2 presents the intercorrelations between the constructs in this study, being the scores on the pretest, the scores on the posttest, the number of items activated during prior content knowledge activation, the scores on the strategic knowledge test, and the number of items activated during prior metacognitive knowledge activation.

<Insert Table 2>

These intercorrelations shows a strong positive correlation between the pre- and posttest, which is to be expected. However, while this table shows that the amount of prior knowledge activated is positively correlated with post-test performance, no such

correlation with the post-test was found for activating strategic knowledge. Finally, the strongest correlation was between strategic knowledge and the number of strategies activated.

In order to check for differences on the pre-test, a 2 x 2 univariate analysis with prior metacognitive knowledge activation and prior topic knowledge activation as independent variables and pre-test scores as dependent variable was executed. No main effects were found for prior metacognitive knowledge activation ($p = .07$) nor for prior topic knowledge activation ($p = .47$), nor did we find an interaction. Similarly, we checked for differences on the strategy knowledge questionnaire, but found no main effects for prior metacognitive knowledge activation ($p = .12$) or prior topic knowledge activation ($p = .96$), nor an interaction ($p = .36$). Furthermore, we included age as a covariate, as there were significant differences in the conditions ($p < .001$). There were no significant differences for gender ($p = .20$).

A 2 x 2 univariate analysis with prior metacognitive knowledge activation and prior topic knowledge activation as independent variables, post-test score as dependent variable, and pre-test and strategy knowledge as covariates was executed. The pre-test was a significant covariate $F(1, 87) = 10.51$, $p = .002$, $\eta_p^2 = .12$, as was age, $F(1, 87) = 5.03$, $p = .03$. Strategic knowledge was not a significant covariate, $F(1, 87) = 1.345$, $p = .25$. The analysis had a power of .99 and an R^2 of .29.

We found a main effect for prior metacognitive knowledge activation, $F(1, 87) = 8.00$, $p = .006$, $\eta_p^2 = .090$, with participants activating their prior metacognitive knowledge outperforming those who had not on the post-test. We did not find a main effect for prior topic knowledge activation, $F(1, 87) = 1.40$, $p = .240$.

<Insert Table 3>

There was an interaction effect between PMKA and PTKA on performance scores on the post-test (see Figure 1), $F(1, 87) = 7.043$, $p = .010$, $\eta_p^2 = .080$. This interaction showed that the effectiveness of activating metacognitive knowledge was highest, but there was no additive effect of prior topic knowledge on prior metacognitive knowledge. Rather, it seems that activating prior topic knowledge actually limited the effectiveness of also activating prior metacognitive knowledge. Table 4 presents a simple effects analysis of PMKA and PTKA.

<Insert Figure 1>

<Insert Table 4>

Discussion

In this study, we investigated whether activating prior topic or metacognitive knowledge led to better text comprehension. We expected that participants engaging in prior topic knowledge activation (Hypothesis 1) or prior metacognitive knowledge activation (Hypothesis 2) would outperform the control condition. Which of the two ways of activation proved to be most effective, was an open question (Question 3).

With regards to activating prior metacognitive knowledge, the results showed statistically detectable results in line with our Hypothesis 2, in that participants who had activated their prior metacognitive knowledge outperformed the control condition. These findings are in line with research attributing difficulties with metacognitive skills to production difficulties, which indicate that students may benefit from receiving metacognitive cues during task performance (Jacobse & Harskamp, 2009; Veenman, Kok, & Blöte, 2005). However, rather than trying to stimulate metacognitive skills during

task performance as was done in those studies, the current study had students activate their knowledge before task performance which also proved effective for students.

Our results did not support Hypothesis 1, in that prior topic knowledge activation did not lead to statistically detectible higher scores on the post-test. This is not in line with prior research indicating the beneficial effects of prior knowledge activation (Amadieu et al., 2009; Chi et al., 1994; De Grave et al., 2001; Ozuru et al., 2009; Pressley & Hilden, 2006). While an explanation might be sought in students not having sufficient prior knowledge to activate, thus not resulting in an effect, this is not supported in our data, as participants on average had half of the questions on the pretest right and also activated on average four items during prior knowledge activation. One possible explanation comes from prior research indicating the way one activates prior knowledge influences how well that knowledge gets activated (Wetzels et al., 2011), and that in the current study, prior content knowledge was not activated in the right way.

However, another possible explanation may lie in the interaction we found between PTKA and PMKA. Our results actually showed that activating prior topic knowledge hindered the effectiveness of prior metacognitive knowledge activation. Although we posited in the introduction that studies thus far had not explicitly activated prior metacognitive knowledge, this is not to say that this did not happen implicitly. For example, in the study by Wetzels et al. (2011) participants were asked not only to *"...bring to mind everything you know about the electrical system and the functioning of the heart..."*, but also to *"...Try to establish relations between the different things you already know..."* While the first quote can be said to deal exclusively with the actual content matter at hand, the second quote actually tries to get students to link parts of the

information together, which can likely be interpreted as a metacognitive activity. Also in their second condition, Wetzels et al. asked students to *"take the perspective of a blood cell that travels through the heart…"*, which likely requires planning and monitoring while activation prior knowledge, thereby having metacognitive aspects.

In our study, while students in the PMKA were instructed to only think and write down the strategies they had used during the first text, it is quite possible this also led to implicit activation of prior topic knowledge, as thinking on the meta-level necessarily requires something to be "meta" about, i.e., the object level (Nelson & Narens, 1994). Our study puts former findings in a new light, as it may be that activation of the metacognitive parts of prior knowledge may have led to positive results in activation studies, rather than the topic knowledge.

There were some limitations to this experiment. First, here, we chose to activate prior knowledge by having students write down their prior knowledge in keywords. While this seems quite productive, writing is much slower than actual thought (Gould, 1980), so perhaps recording think-aloud and writing out protocols may be a different option that produces better results (see Wetzels et al., 2011).

Also, in this study we assumed that activated knowledge was accurate. Studies by Dinsmore and Parkinson (2013), and Van Loon, De Bruin, Van Gog, and Van Merriënboer (2013), have shown that students may activate prior knowledge that is not (entirely) correct and that students may not be aware that this prior knowledge may be faulty.

Finally, participants were selected to fit with the difficulty of the text level. Because this provided a rather selective group of participants, one can wonder about the

generalizability of the results. While further research is certainly necessary to extend this research beyond this specific group of participants, it seems likely that if students have some sort of prior knowledge (whether that is topic knowledge or metacognitive knowledge), their learning can benefit from activating this knowledge, as was shown in prior studies (Wetzels et al., 2011).

To consolidate the effects of activating prior metacognitive knowledge found in this study, several avenues of research remain open. Investigations should be made into the effectiveness of prior metacognitive knowledge activation and direct instruction of metacognitive knowledge between students with different levels of topic and metacognitive knowledge, requiring accurate instruments for assessing metacognitive knowledge in text comprehension. Also, more longitudinal research is required to show possible long-term benefits of direct instruction or prior knowledge activation of metacognitive skills. Finally, as prior research has shown expository texts lead to more utilization of prior topic knowledge compared to narrative texts (Wolfe & Woodwyk, 2010), there may also be effects of the type of text on prior metacognitive knowledge activation.

The results of this experimental study provide evidence that activating prior metacognitive knowledge leads to enhanced performance scores on text comprehension. More research is needed with regards to educational practice, such as how teachers could achieve long-term results with prior knowledge activation, and what types of prior knowledge activation work best within educational practice. Moreover, the results of this study suggest that if students have specific knowledge, whether this is cognitive, metacognitive or perhaps even motivational knowledge, it should not be expected that

students will have this knowledge at-the-ready, but that this knowledge may need to be activated in order to further enhance learning.
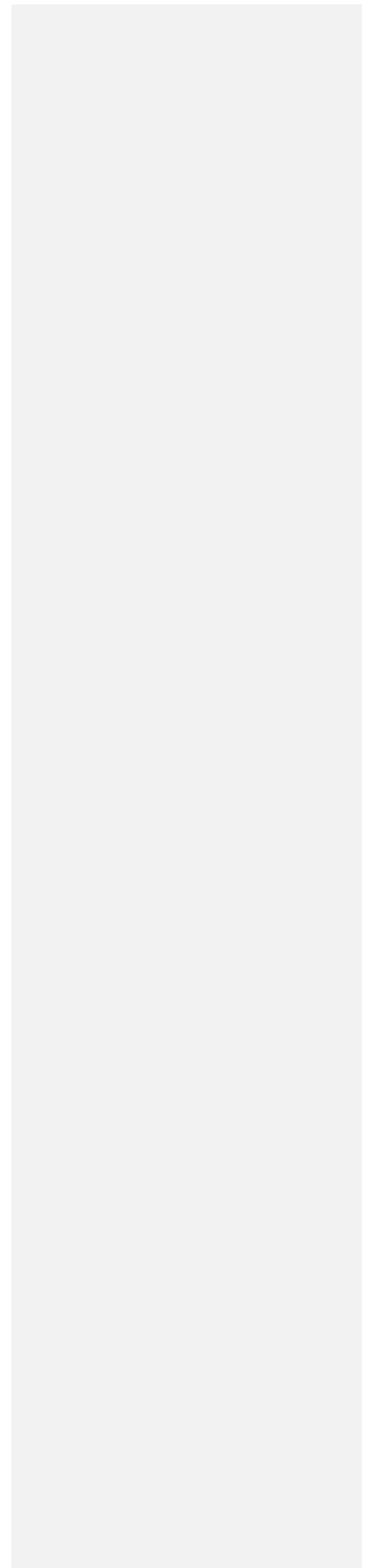
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Table 1

Descriptives of Conditions

	n	Mean Age	% Girls
Control	22	11.00 *(.62)*	41
PTKA	22	11.73 *(.55)*	36
PMKA	22	11.73 *(.62)*	59
Both	22	11.09 *(.75)*	64

Table 2

Inter-correlations

	1	*2*	*3*	*4*	*5*
1. Pretest score	1	.32**	-.02	.00	-.15
2. Posttest score	.32**	1	.33*	-.18	-.27
3. # terms activated	-.02	.33*	1	.11	.15
4. Strategic knowledge	.00	-.18	.11	1	.50**
5. # activated strategies	-.15	-.27	.15	.50**	1

* *p* < .05, ** *p* < .01

Table 3

Mean (standard deviation) for Pre-test, Post-test and Strategic Knowledge test.
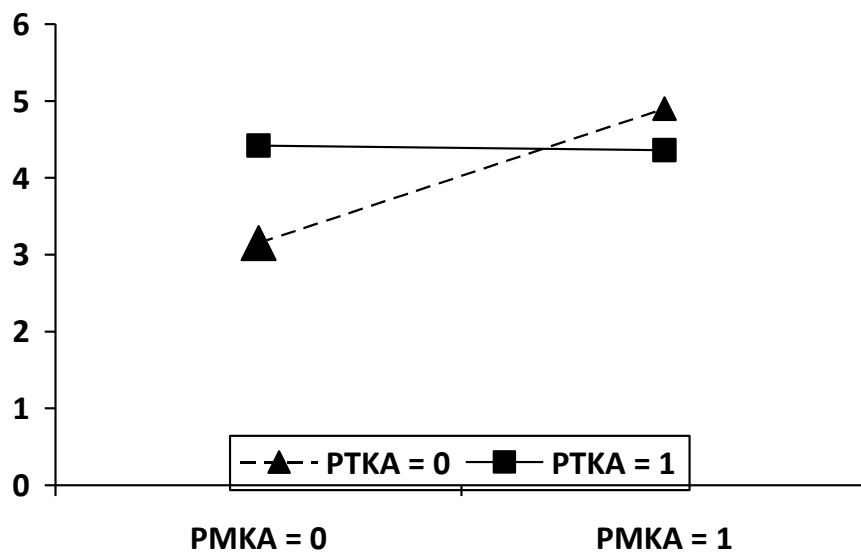
	Pre-test	**Post-Tests**	**Strategy knowledge**
Control	4.09 *(1.80)*	3.36 *(1.18)*	14.64 *(5.31)*
PTKA	4.41 *(1.71)*	4.36 *(1.62)*	13.68 *(4.02)*
PMKA	4.00 *(1.63)*	4.82 *(1.53)*	12.18 *(4.17)*
Both	3.14 *(1.83)*	4.32 *(1.67)*	13.05 *(4.74)*

Table 4

Simple Effects

(I)	(J)	I - J	Std. error	Sig.
Control	PMKA	-1,79	.46	< .001
	PTKA	-1,27	.46	.007
	Both	-1.21	.43	.006
PMKA	PTKA	.51	.42	.23
	Both	.57	.46	.21
PTKA	Both	.06	.47	.90

Figure 1. Interaction between conditions

Appendix 1

Example items text part 1

1) What is the meaning of the word "Geothermic"?

a. Earth-energy

b. Warmth from the Earth

c. Volcanic activity

d. Global warming

2) What causes heat within the Earth's core?

a. Pressure

b. Magma

c. Radioactivity

d. Geothermal energy

Example item text part 2

4) What is true about gathering geothermic energy?

a. Geothermal energy is infinite.

b. Geothermal energy is not replenished.

c. Geothermal energy is insufficient for our energy needs.

d. Geothermal energy is inexpensive.

Appendix 2

1. I look at the title of the text to see what it is about.

2. I look at the pictures of a text to see what the text is about.

3. I try to think in advance what I know about the subject of a text.

4. I try to think how much time a reading assignment is going to take me.

5. I look at the questions of an assignment before starting to read.

6. I try to determine what I want to learn from a reading task.

7. I reread difficult parts of a text.

8. I keep asking myself whether I understand what I am reading.

9. I try to make summaries.

10. I read every question carefully.

11. I think about each possible answer to a question.

12. When I finish, I recheck my answers.