The influence of verbal elaboration on subsequent learning: An experimental study in a PBL-setting

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Abstract: Problem-based group discussions are expected to enhance activation of and elaboration on prior knowledge. Some experiments reported improved recall after problem-based group discussions. However, these experiments did not control for individual differences in prior knowledge and quality of discussions. This experiment aimed to keep these variables under control. 62 students were trained on a physical topic (waves). One week later, they observed a video-recorded problem-based group discussion. In the experimental condition, students observed a discussion relevant to the trained material and verbally participated. In two control conditions, students either observed the relevant or an irrelevant discussion, without participating verbally. Then, all participants studied a relevant text. Immediate and delayed cued recall measures were taken. The experimental group was expected to recall more correct propositions than both control groups. A preliminary analysis with a one-way ANOVA showed a significant difference between the conditions on the delayed, but not on the immediate measure. A tentative conclusion therefore is that the verbal participation improved long-term recall.

Introduction
The role of elaboration and prior knowledge in learning

In the learning psychology literature, a considerable amount of research describes elaboration as a powerful learning facilitator (e.g. Bobrow & Bower, 1969; Dansereau, 1978; Mayer, 1980; Mayer and Cook, 1981; Slamecka & Graf, 1978). Elaboration may generally be defined as meaningfully connecting new parts of information with each other, or meaningfully relating new information to prior knowledge (Levin, 1988; Mayer, 1980; Reder, 1980). It relates to what Craik and Lockhart (1972) call 'depth of processing', where deeper levels of processing mean more thorough and effortful attempts to understand new information, for instance by connecting it with experiences from the past.

More specifically, Mayer (1980) distinguishes three types of elaboration. The first type, *associative elaboration*, is elaboration by means of meaningfully associating multiple stimuli. This type of elaboration is based on findings with word-pairing experiments, for instance by Bobrow & Bower (1969) and Slamecka & Graf (1978). In these experiments, participants learned pairs of unrelated words. By using both words in one meaningful sentence, participants were better able to remember the pairs.

The other two types of elaboration Mayer (1980) proposes are *integrative* and *comparative elaboration*. These two are rooted in learning from prose, rather than memorizing word pairings. Integrative elaboration can be explained as the meaningful integration of new information with prior knowledge, while comparative elaboration refers to elaboration by explaining relations between new information. Thus, learners either meaningfully relate new information with existing knowledge structures, or establish these relations by comparing different pieces of new information with each other.

In two experiments, Mayer (1980) and Mayer and Cook (1981) showed positive effects of elaboration on various learning outcomes. In one experiment, (Mayer, 1980), they provided participants with either a strategy to enhance their integrative elaboration, a strategy to enhance their comparative elaboration, or no learning strategy at all. The integrative elaboration strategy entailed studying a text while relating the text passages with familiar analogies, while the comparative elaboration strategy consisted of comparing the passages with each other. Participants who used one of the two strategies solved relatively complex problems more often. Furthermore, participants who used the integrative elaboration strategy recalled more conceptual information, i.e. information that explained the consequences of the programming rules. In contrast, they recalled less descriptive, factual information.

In the past decades, several elaboration-enhancing interventions have been developed (e.g. Dansereau et al., 1978). Some of these indicate a positive effect of verbal explanation on learning (Chi et al., 1989, 1994; King, 1990; Pressley et al., 1990, 1992; Woloshyn, Pressley & Schneider, 1992). Producing verbal explanations has since long been known as a method to reflect upon one's own thoughts, leading to a 'recoding' and change of knowledge (Prawat, 1989). A review by Webb (1989) reported positive relations between explaining what

one has learned to peers and one's own learning performance. Moreover, these relations are found more often when the produced explanations are elaborative, whereas they are less common when the explanations are non-elaborative (e.g. when only the answer is given). Webb (1989) argues that:

> "In explaining to someone else, the helper must clarify, organize, and possibly reorganize the material […] In the process of clarifying and reorganizing the material, the helper may discover gaps in his or her own understanding, or discrepancies with others' work or previous work. To resolve these discrepancies, the helper may search for new information and subsequently resolve those inconsistencies, thereby learning the material better than before."

Some experiments support the notion that explaining to others particularly promotes learning when the given explanations are elaborative. For example, Webb, Troper and Fall (1995) let 7th graders explain math problems to each other, as part of a math course. Students of similar math ability were placed in small study groups and discussed several math problems with each other. All verbal help they provided each other with was tape-recorded. Also, the subsequent activities students engaged in after receiving this help was registered. Both the help received and the subsequent activities were evaluated according to their quality, ranging from low-elaborative (no constructive help or activity) to high-elaborative (an elaborate help or activity). At the end of the course, the students received a posttest consisting of math operations. There was no positive correlation between the help received and achievement, but the highest level of constructive activity (i.e. reworking the entire problem or explaining how to solve it to other students) did show a positive relation with performance on the operations. Thus, receiving elaborate explanations did not lead to a better performance, while engaging in highly elaborative activities did.

In an experiment by King (1990), university students listened to a lecture. After the lecture, half of the students discussed the lecture without any prior instruction. The other half had been trained to ask elaborative questions, i.e. specific, thought-provoking questions, before the lecture, such as: "What is the difference between … and …?" (1) Students who were trained asked more critical questions, gave more high-level elaboration responses and showed better understanding of the lecture than the control group. Understanding was measured with a combination of multiple-choice and open-ended questions.

Chi et al. (1989) found that students who gave high-quality explanations while studying worked-out mechanical problems were better able to solve problems than students who gave low-quality explanations. Also, Chi et al. (1994) discovered that encouraging students to explain the blood circulatory system resulted in a more complete understanding of this system. All students read a text passage about the blood circulatory system. Half of them (the 'prompted' group) was encouraged to explain what they had read after each sentence. The other half (the control group) merely read the text twice. The prompted group showed a greater learning improvement about the blood circulatory system, especially on complex questions that required inference and application, than the control group. Moreover, the participants in the prompted group who explained most, showed more learning improvement than those who explained less. This difference was only significant for the relatively complex questions. Thus, explaining especially seemed to improve complex understanding.

However, prior knowledge seems to influence the positive effects of explaining on learning. For example, some authors argued that an elaborative strategy like asking and answering 'why questions' activates prior knowledge, which in turn can be related to new information (Pressley et al., 1992). (2) In one experiment (Woloshyn, Pressley & Schneider, 1992), participants studied geographical facts about either areas their home country or areas in another country. After each fact, half of the participants asked themselves out-loud why it made sense that it was related to that particular area they had just studied. The other half was instructed merely to understand the information. After this task, all participants performed a matching task, in which they had to match the facts with the corresponding geographical areas. Participants who had asked the elaborative 'why-questions' made more correct responses when they had studied areas of their home country than when they had studied areas of the other country. Thus, their prior knowledge had a significant impact on their learning, even while elaboration was promoted for both groups. In other words, the elaboration strategy was especially effective when prior knowledge was present. A study by Willoughby et al. (1993) reported similar finings with different study topics.

To conclude, learning can be enhanced by elaboration in several ways. In order to create meaningful relations, one can integrate new information with existing knowledge schemes, or make a conscious attempt to draw comparisons between new concepts. Verbal explanation is a useful method for elaboration, especially when the produced explanations are in-depth and prior knowledge about the subject is present.

Elaboration and prior knowledge activation in problem-based learning

Problem-based learning (PBL) is an educational approach that is largely based on prior knowledge activation and elaboration (Schmidt, 1983). Also, a large role is attributed to verbal explanation of the subject-matter to others. In practice, these principles are applied as follows. First of all, students gather in groups and analyze a problem or case that is related to their field of study. During this analysis, they collectively try to

activate as much prior knowledge as possible. (3) Then, they discuss relations between their retrieved prior knowledge, identify what information is relevant to the problem, and synthesize the information. This elaborative discussion is expected to restructure their knowledge within the context of the problem (Schmidt, 1993; Schmidt et al., 1989), which constructs a foundation for self-study. Because their knowledge framework has been restructured in a meaningful, context-sensitive way, subsequent self-study is expected to be facilitated.

From a learning perspective, this rationale behind PBL seems to be consistent with the abovementioned studies. PBL promotes explaining to others, which may lead to a restructuring of knowledge and better in-depth understanding. Also, it stimulates the activation of prior knowledge during the group discussion. Moreover, students are encouraged to engage in comparative and integrative elaboration, as they exchange and compare their prior knowledge with each other. Elaboration may be continued during self-study, when students are able to compare new information with the synthesized information from the group discussion.

In experimental settings, some evidence has been reported that supports PBL's assumption that elaboration and prior knowledge activation facilitate learning. Schmidt (1984) let participants without an extensive biological background study a text on osmosis and diffusion. Prior to studying, half of the participants (the experimental condition) discussed a problem about a shrinking and expanding blood cell in small groups. This allowed them to activate relevant prior knowledge related to osmosis and diffusion. The other participants (the control condition) did not engage in any discussion. Participants in the experimental condition recalled more information from the text than those in the control condition. However, the average amount of inferences from the text produced by the two groups did not differ. An increased amount of self-generated inferences may be expected as a result from meaningful elaboration on prior knowledge (Schmidt, 1984).

In a later experiment, Schmidt et al. (1989) found that participants who discussed the blood cell problem recalled significantly more from the osmosis and diffusion text than participants who discussed an irrelevant problem. Moreover, participants in the former condition recalled more explanatory information than participants in the latter condition. In contrast, there were no differences in recall for descriptive, i.e. factual information. The authors argued that the relevant (i.e. blood cell) discussion triggered a context-relevant activation of prior knowledge, which enabled participants in this condition to construct a mental model about the subject. This model then formed a foundation for further study, which made it easier for them to process the osmosis and diffusion text.

The participants in Schmidt's (1984) and Schmidt et al.'s (1989) studies were high school students. DeGrave, Schmidt & Boshuizen (2001) did a similar study in a contextually more valid environment, namely a PBL medical curriculum. They let students engage in small group discussions about a problem from the existing medical curriculum. As in Schmidt et al.'s (1989) experiment, half of the groups discussed a relevant problem and the other half an irrelevant problem. Subsequently, all students read a text that followed the relevant problem and performed a free recall test. Students who had discussed the relevant problem recalled more from the text than students who discussed an irrelevant problem. Differences between recall of explanatory and descriptive information were examined too, but no differences were found.

In an even more ecologically valid setting, Capon and Kuhn (1994) conducted a PBL-study as part of a university course. All participants received both problem-based and lecture-based education and were assessed half-way and at the end of the course. Half of the participants started with PBL and the other half with lecture-based learning. At the first assessment, the lectured students showed superior factual knowledge, but at the second assessment, the PBL students were better able to give explanations beyond the formal definitions from the books. The authors tentatively concluded that PBL does not enhance better recall of factual information, but does lead to a better integration of new concepts in existing knowledge structure, similar to integrative elaboration.

In sum, there is some experimental and field-research evidence for the positive influence of PBL-discussions on subsequent learning, especially learning of higher-order, explanatory information. However, evidence for a better recall of explanatory (versus descriptive) information was not found in all studies. Furthermore, learning of facts seemed to be unaffected or worsened in PBL educational formats.

Research questions and hypotheses

Although PBL-studies provided new insights on the learning effects of PBL, they had to deal with some shortcomings. First of all, none of the PBL-experiments controlled for individual differences in prior knowledge. It is possible that some of the study groups in the experiments contained more knowledgeable students than others. Therefore, collective learning of the whole discussion group may have been influenced by one or a few individuals who knew most. Also, it is possible that some groups engaged in discussions that were qualitatively superior to the discussions of other groups. In order to investigate the net learning effects of prior knowledge activation and subsequent elaboration, it is necessary to control for these two confounding variables.

The aim of this experiment is to investigate the effect of prior knowledge activation and elaboration during a PBL discussion group on learning. The research question is whether verbal activation of prior knowledge and elaboration facilitates subsequent learning and hence leads to better recall of correct information.

It is hypothesized that activation and elaboration lead to a higher amount of correctly recalled propositions on a short and long-term.

Method
Participants
69 participants started the experiment, of which 62 finished it. All were students from Maastricht University's Faculty of Psychology, Health, Medicine and Life Sciences, Cultural Sciences, or Economics and Business Administration. Their average age was 20 years ($SD = 1.59$). All participants reported not to have written a final high school examination in physics and received financial compensation for their participation.

Materials
The materials were presented in Dutch and inspired by a text about radar waves used by Mayer and Cook (1981; also see Mayer, 1985). This text served as an example to construct two new texts. The first text explained the physical principles of waves. Its purpose was to create a basic understanding of waves, which served as a foundation of prior knowledge for understanding the second text. The second text explained, among other things, the basic functioning of radar, how it uses electromagnetic waves to measure distance, position and bearing of airplanes, why it uses electromagnetic waves, how these waves extinct under normal circumstances and how this extinction can be prevented (namely by focusing the waves into a straight ray).

For the experimental and first control condition, a problem was written that described an air traffic controller who managed the radar system of Amsterdam Airport. His main problem was to make sure an adequately strong signal returned to the radar. In order to achieve this, he needed to take into consideration the energy loss of the electromagnetic waves. For the second control condition, an irrelevant problem about alcohol was written.

Two group discussions were digitally recorded in a professional studio. In both discussions, three students questioned a fourth about issues that related to the problem. The first discussion was based on the radar problem and meant for the first control group to see. An edited version of this discussion, showing only the questions by the three students, was created for the experimental condition. The second discussion was based on the irrelevant alcohol problem and aimed for the second control group. Both discussions were scripted beforehand and practiced and performed by the same four students.

Three sets of nine MC-questions about the first text were constructed. Each question was based on one text passage and each set of questions covered all passages in text 1. Thus, there were nine passages, each with three matching MC-questions. In addition, thirteen open-ended questions about the second text were constructed. All materials were presented electronically and in single-person, isolated computer rooms.

Procedure
In a pre-experimental phase, all participants learned some basic physical principles about waves, in order to provide them with a homogenous level of prior knowledge that they could use during the experimental phase. All participants studied the first text for ten minutes and answered the first set of nine MC-questions. Based on a procedure by Chi et al. (1994), they reread the text for seven minutes if they were not able to answer all nine questions correctly. Subsequently, they received a 'retest', a subset of questions from the second set that covered the ill-understood text passages. If not all of these questions were answered correctly, they again reread the text. This time, however, they only read those passages that were not understood (i.e. they had failed to answer its' matching question correctly). After this third study phase, they received a subset of questions from the third set that covered these passages.

One week after the pre-experimental phase, all participants returned and were assigned to either the experimental (N = 21), first control (N = 20) or second control condition (N = 22). The experimental group read the radar problem and was subsequently watched the edited version of the radar problem-discussion, which contained only the questions from three students. While watching the discussion, these participants were instructed to answer the questions and to come up with as much information from the pre-experimental training as possible. They received 20 to 40 seconds in between each question to answer. The questions either referred to information from the first text (e.g. "What was the relation between the particles and the wave's speed?"), information from the first text within the context of this problem (e.g. "What is the difference between sound waves and electromagnetic waves?"), not to any prior knowledge at all (e.g. "What is a pulse?"). (4) The answers were tape- and digitally recorded.

The first control group read the radar problem and watched the unedited radar problem-discussion. Participants in this condition were instructed to watch the discussion and keep in mind information from the pre-experimental training. The second control group read the irrelevant problem and watched the alcohol problem-discussion. This group received no further instruction.

Immediately after the group discussion, all participants read the second (radar) text for twenty minutes. This text provided answers to all questions that were posed in the group discussion about radar. Immediately after reading the second text, all participants answered the thirteen open-ended questions. After one month, they answered the same 13 questions again.

Analyses

Recall analyses were based on the second text. The author parsed this text into propositions. Following Schmidt et al. (1989), a proposition was defined as a single idea, identified as a subject-predicate unit with linguistic markers (like conjunctions, adverbs and adverbs) as demarcation points. Next, the author and three independent judges scored all the answer protocols. In order to improve objectivity, each judge blindly scored an equal amount of answer protocols from each condition. Following the same procedure as the second text, the judges parsed the answer protocols into propositions. Initially, the inter-judge agreement between the author and one of the judges, and between the two other judges, was calculated for a total of six completely parsed answer protocols. This agreement was 89%. Future differences were resolved by discussion.

Subsequently, the author and judges evaluated the correctness of the propositions, based on propositions from the parsed second text. The inter-judge reliability for this evaluation was initially calculated in the same manner as had been done for the propositions, which resulted in an agreement of 79%. Again, future differences were resolved by means of discussion. Paraphrases from the questions and repeated answers were not scored.

A one-way ANOVA with condition as independent variable and amount of false and correct propositions on both measurement intervals as dependent variables was used to investigate differences in correct recall between the three experimental conditions.

Table 1: Mean amount of correct propositions per condition and measurement interval (standard deviations between brackets).

Condition	Mean amount of correct propositions	
	Direct measure	*Delayed measure*
Experimental	63.25 (30.10)	54.25 (26.95)
First control	56.40 (18.41)	38.60 (15.01)
Second control	50.05 (20.83)	41.77 (18.77)

Preliminary results and discussion

It was expected that the experimental group produced more correct propositions than both control groups. For the direct measure, the one-way ANOVA did not reveal any differences between the mean amount of correct recall, $F (2, 59) = 1.65$, $p < .21$. However, there was a significant difference between the three groups on the second, delayed measure, $F (2, 59) = 3.19$, $p < .05$. The means and standard deviations of correct recall are reported in table 1. The mean amounts of false propositions did not yield any significant differences, $F (2, 59) = 1,45$, $p < .25$ for the direct measure, and $F (2, 59) = .68$, $p < .52$ for the delayed measure.

Subsequent t-tests showed that, on the delayed measurement interval, there was a significant difference in mean amount of correctly recalled propositions between the experimental group and the first control group (i.e. the group that observed the relevant condition, but did not participate), $t (38) = 2.27$, $p < .05$. However, the difference between the experimental condition and second control condition (irrelevant discussion and no participation) did not reach significance on the second measurement interval, $t(40) = 1.76$, $p < .09$.

These results provide some partial evidence for the hypothesis. It was expected that the experimental group outperformed the control groups on both the immediate and delayed recall measures. The finding that it only seemed to do so after one month, raises several hypotheses. First of all, it is possible that the experimental group indeed remembered the information better due to their activating and elaborative activities. Reder (1980) argued that elaborations can lead to redundancy in memory, which may enhance long-term recall. However, this experiment has not assessed yet to what extend the participants in the experimental group activated prior knowledge and elaborated. Also, it is possible that the amount of participants was too low and therefore the study's power is insufficient. Power estimates still need to be performed and perhaps the sample needs to be increased.

The unnatural setting in which this experiment was conducted provides a drawback, which can partly be resolved by simulating 'real life', scripted PBL discussions in future experiments. However, it is very hard to control for confounding variables like differences in group discussion and prior knowledge, without adding some degree of experimental control.

Endnotes

(1) This could be an example of a question that stimulates comparative elaboration.
(2) This strategy may be regarded one to promote integrative elaboration.
(3) At Maastricht University, this knowledge is written down on the blackboard.
(4) The questions were not specifically designed to evoke elaborative deep thinking, like for instance King's (1990) questions did (e.g. "How would you use … to …?").

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