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Theoretical Analysis

Drawing pictures during learning from scientific text: testing the generative drawing effect and the prognostic drawing effect

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ABSTRACT

Does using a learner-generated drawing strategy (i.e., drawing pictures during reading) foster students' engagement in generative learning during reading? In two experiments, 8th-grade students (Exp. 1: $N = 48$; Exp. 2: $N = 164$) read a scientific text explaining the biological process of influenza and then took two learning outcome tests. In Experiment 1, students who were asked to draw pictures during reading (learner-generated drawing group), scored higher than students who only read (control group) on a multiple-choice comprehension test ($d = 0.85$) and on a drawing test ($d = 1.15$). In Experiment 2, students in the learner-generated drawing group scored significantly higher than the control group on both a multiple-choice comprehension test ($d = 0.52$) and on a drawing test ($d = 1.89$), but students who received author-generated pictures in addition to drawing or author-generated pictures only did not. Additionally, the drawing-accuracy scores during reading correlated with comprehension test scores ($r = .623$, $r = .470$) and drawing scores ($r = .620$, $r = .615$) in each experiment, respectively. These results provide further evidence for the generative drawing effect and the prognostic drawing effect, thereby confirming the benefits of the learner-generated drawing strategy.

1. Introduction

Suppose you want to enable students to study a scientific text by themselves for deep level understanding. In this case, you will have to ensure that students engage in generative learning processes during reading, such as organizing material into coherent mental representations, and integrating the representations with each other and with relevant knowledge activated from long-term memory (de Jong, 2005; Mayer, 2004, 2009; Wittrock, 1990). A possible way to accomplish this goal is to encourage students to use a *learner-generated drawing strategy* (Alesandrini, 1984; Schwamborn, Mayer, Thillmann, Leopold, & Leutner, 2010; van Meter & Garner, 2005), in which they receive a text to read and are instructed to draw pictures that reflect the main elements and relations described in the text. The goal of the present study is to examine a generative drawing effect (i.e., engaging in appropriate drawing activities during learning from text improves performance on tests of learning outcomes) and a prognostic drawing effect (i.e., the quality of drawing during learning from text predicts performance on subsequent tests of learning outcomes).

1.1. Theoretical framework for the learner-generated drawing strategy

A straightforward way to encourage students to use a learner-generated drawing strategy when learning from verbal instruction is to ask them to generate an external visual representation of a to-be learned content. The drawing that is generated has a representational quality, similar to the characteristics of a representational illustration (cf., Alesandrini, 1984; van Meter & Garner, 2005). By representational, we mean that learners make drawings which are intended to show what depicted objects look like (Carney & Levin, 2002). This requirement excludes nonrepresentational graphic constructions such as diagrams and concept maps. Thus, our definition of drawing is that the learner creates a visual representation intended to depict what is described in text.

Drawing can be seen as a learning strategy intended to influence how learners process information during learning (Pashler et al., 2007; Weinstein & Mayer, 1986). By drawing, learners are no longer passive consumers of information and knowledge; they are

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actively involved in the cognitive processes of selecting, organizing and integrating the information to be learned. Thus, learner-generated drawing is a cognitive learning strategy that is aimed to foster learning from text, and if used adequately drawing can increase learning outcomes (Ainsworth, Prain, & Tytler, 2011; Alesandrini, 1984; van Meter & Garner, 2005).

The processes underlying drawing are described in van Meter and Garner's (2005) generative theory of drawing construction (GTDC), which is based on Mayer's (2005) model of multimedia learning. It is assumed that learners benefit from using the drawing strategy as drawing requires them to engage in generative learning processes during reading. First, learners select the relevant key information from the text. Second, the selected key information is organized to build up an internal verbal representation of the text information. Third, learners construct an internal nonverbal (visual) representation of the text information and connect it with the verbal representation and with relevant prior knowledge. To construct the visual representation, which is the basis for the external drawing, the learner has to rely mainly on the verbal representation, and thus learner-generated drawing demands an integration of the verbal and nonverbal representation.

Additionally, van Meter and Garner (2005) describe metacognitive processes fostered by the drawing activity: "Attempts at constructing the nonverbal representation can send learners back to either the verbal representation or the text as difficulties building the internal image are encountered" (van Meter & Garner, 2005, p. 317). That is, as the drawing process itself is not linear, metacognitive processes of monitoring and regulation are stimulated by drawing (cf., van Meter, 2001; van Meter, Aleksic, Schwartz, & Garner, 2006).

1.2. Empirical framework for the learner-generated drawing strategy

Following the GTDC (cf., van Meter & Garner, 2005), the drawing strategy is beneficial as it fosters deep cognitive processing including organizing and integrating material (which can be called *generative processing*; Mayer, 2009) as well as metacognitive self-monitoring and regulation processes. Research on drawing, however, has produced somewhat mixed results (see Alesandrini, 1984; van Meter & Garner, 2005, for overviews) in which some studies reported positive effects of drawing on text comprehension (e.g., Alesandrini, 1981; Hall, Bailey, & Tillman, 1997; Leopold & Leutner, 2012; Lesgold, DeGood, & Levin, 1977; Lesgold, Levin, Shimron, & Guttman, 1975; Schwamborn et al., 2010; van Meter, 2001; van Meter et al., 2006), whereas others did not (e.g., Leutner, Leopold, & Sumfleth, 2009; Rasco, Tennyson, & Boutwell, 1975; Tirre, Manelis, & Leicht, 1979). Benefits of drawing appear to be related to the quality of students' drawings during learning: Students, who produce high-quality drawings during reading, tend to score better on posttests of learning outcome than do students who produce low-quality drawings during reading (e.g., Greene, 1989; Hall et al., 1997; Leopold, 2009; Lesgold et al., 1975, 1977; Schwamborn et al., 2010; van Meter, 2001; van Meter et al., 2006).

1.2.1. Effectiveness of learner-generated drawings

Following van Meter and Garner (2005), reasons for the mixed empirical results concerning drawing can be seen attributed to the type of test used for assessing learning outcomes as well as in the form of support that assists learners in the drawing process. First, benefits of drawing are more likely to be revealed on tests that assess higher-order knowledge of to-be learned content, for example, tests on comprehension and transfer (e.g., Alesandrini, 1981; Leopold & Leutner, 2012) or problem solving (van Meter, 2001; van Meter et al., 2006). Leutner et al. (2009), for example, found no positive effect of drawing compared with a control group on a multiple choice test on factual knowledge. Leopold and Leutner (2012), however, showed superior effects of the drawing strategy on transfer test performance. van Meter et al. (2006), accordingly, found no effects of drawing activity on a multiple choice recognition test; however, students in the drawing group scored significantly higher on a problem-solving test. With regard to the GTDC (van Meter & Garner, 2005), it seems that benefits of drawing can be found if the learning outcome test complies with characteristics of the verbal and nonverbal representations, which are generated by drawing.

Second, positive effects of drawing often appear under the condition that instructional support is provided to constrain and structure the drawing activity (e.g., Lesgold et al., 1975, 1977; Schwamborn et al., 2010; van Meter, 2001; van Meter et al., 2006). That is, drawing is more effective when the learners' generation of the drawing is assisted by some kind of additional information. van Meter (2001) and van Meter et al. (2006), for example, showed that the provision of author-generated pictures after drawing enhanced the benefits of the drawing strategy. By comparing their own drawing with a provided one, learners get to know what their drawing should look like, and this might lead them back to revise their own drawing and thus, their mental model. Following the GTDC (van Meter & Garner, 2005), this should improve comprehension. Lesgold et al. (1975), in turn, supported first grade students with cutout figures and instructed them to organize these into an accurate pictorial representation while listening to a prose story. This learner-generated illustration activity facilitated prose learning as indicated by higher recall of story propositions only when students were given the correct pieces for the illustration or had the illustration done for them. When students had to select the pieces for each illustration out of a pool of cutouts, the learner-generated illustration activity had either a negative or no effect (cf., Lesgold et al., 1977). Following these results, Schwamborn et al. (2010) proposed that a pure, unsupported drawing instruction might bear the risk that managing the mechanics of drawing itself is difficult for the learners, resulting in insufficient remaining capacity for making sense of the text through generative processes of organization and integration, which might diminish the benefits of drawing defined by van Meter and Garner's GTDC. To counter this risk in the study of Schwamborn et al. (2010), students in the drawing groups received baseline instructional support while learning a lesson on washing, which provided them with a *drawing prompt* that included a legend showing all the relevant elements for drawing and a partly pre-drawn background for their paper-pencil based drawings. That is, students could use the presented elements as prototypes for their own drawings and integrate them by pencil in the given pre-drawn backgrounds. Results showed that students, who were instructed to generate drawings during learning, scored significantly higher on the subsequent comprehension tests than students who only read the text.

Using cutout-figures (cf., Lesgold et al., 1975, 1977) or a drawing prompt (cf., Schwamborn et al., 2010) during drawing seems to provide sufficient constraints and leave enough cognitive capacities for learners to benefit from the drawing strategy. Thus, cognitive processing including selecting, organizing and integrating material should be encouraged, resulting in an improved mental model, which in turn should improve comprehension (cf., GTDC; van Meter & Garner, 2005).

In line with the GTDC and the reported results derived from research on drawing Schwamborn et al. (2010) proposed a *generative drawing effect*, that is, students gain a better understanding of a scientific text when they are asked to draw illustrations representing the content of each paragraph they read. This work highlights the importance of drawing support, such as the provision of drawings of all key elements and a background for the drawing.

1.2.2. Quality of learner-generated drawings

Previous studies that measured the quality of students' drawings during learning all showed positive correlations between