Journal of Articles in Support of the Null Hypothesis
Vol. 18, No. 1
Copyright 2021 by Reysen Group. 1539–8714
www.jasnh.com

Does the position and emotional valence of decorative pictures (in multimedia learning) influence learning performance?

Maria Mikheeva
Sascha Schneider
Günter Daniel Rey
Psychology of Learning with Digital Media, Faculty of Humanities, Chemnitz University of Technology, Germany

Mathematical know-how is critical for numerous university students. This experiment examined whether decorative pictures in mathematical online learning could enhance learning. Although many experiments indicated a negative impact of decorative pictures, the pictures improved students' learning when they activated learning-relevant emotions and were connected to the learning materials. An experiment was conducted and included two sections, each with decorative pictures, learning materials, and questions. Overall, there were 92 participants. A 2 × 2 between-subjects design was used, employing the factors "picture in the first section" (positive vs. negative), and "picture in the second section" (positive vs. negative). The results showed that pictures neither enhanced nor hindered learning. Possibly, the pictures were overlooked, because they were combined with learning materials.

Keywords: mathematical online learning, decorative pictures, learning emotions, emotion and motivation, multimedia learning.

Acknowledgements:
We would like to thank two students, Anabel Hauschild and Yannik Augustin, for their help with the experiment. This work was supported by the Europäischer Sozialfonds (ESF).

Introduction

Mathematics is a necessary subject in universities for many students, especially in technical fields; however, many students experience difficulty in preparing for examinations. There are several possible reasons for this difficulty: lack of mathematical knowledge gained in school, motivational problems, and/or students being unable to integrate theoretical mathematics knowledge. Many students, therefore, experience mathematics as very abstract. Numerous studies investigated how to improve the teaching of mathematics (e.g., Chiu et al., 2020; Cooper et al., 2018; Lindner, 2020; Mikheeva et al., 2019; Vrugte, et al., 2017), but it remains a problem for universities. Furthermore, when a multimedia design is used to enhance learning, it is important to remember that the learning situation itself can influence learning (e.g., Ginns, 2005; Schneider et al., 2018a).

Moreover, online-learning has become more significant because of the COVID-19 pandemic. Many universities worldwide refused partly or completely of traditional classroom lessons. Possibly, the meaning of online-learning will not decrease after pandemic.

Next, Huk and Ludwigs (2009) examined the question of how to promote learning and investigated the roles of cognitive and affective supports in knowledge acquisition. They showed that, even if cognitive support increased perceived *germane cognitive load* (appearing in the building of new knowledge), a combination of cognitive and affective supports was necessary to improve learning.

Many researchers focused on the cognitive aspects of learning (e.g., Mayer & Mayer, 2005; Sweller, 1994, 2010). The further question is what affective support might look like; for instance, whether decorative pictures could be used to improve learning. The pictures influenced the students' moods but did not explain parts of the learning materials (Schneider et al., 2016). Pictorial illustrations that overlap with the text content and provide supportive information can increase learning (Carney & Levin, 2002), but it is uncertain whether decorative pictures can enhance learning. The seductive detail effect, which relates to interesting but unnecessary information (for example, decorative pictures), was found to inhibit learning (for an overview, see Rey, 2012; Sundararajan & Adesope, 2020), due to learners' limited attention capacity and working memory (Sweller et al., 2011). Many factors, however, could moderate the seductive detail effect, such as arousal (Schneider et al., 2019b) or task experience (Rop et al., 2018). Furthermore, Sundararajan and Adesope (2020) found in their meta-analysis a positive influence of seductive details on learning of mathematics and statistics. Finally, even if decorative pictures could hinder learning, they could also enhance learning in digital environments when the pictures were integrated into a learning context or learning-relevant emotions were simultaneously activated (Schneider et al., 2018b; Schneider et al., 2018c; Schneider, et al., 2016).

One more important aspect is the *valence* or pleasantness of such pictures (Russell, 2003). Many experiments used conditions in which the pictures were either positive or negative, but did not combine positive and negative emotions. Coping models could provide a theoretical basis for a combination of emotions in the same condition (Schunk, 1999). According to such models, it is necessary to present problems at the beginning of tasks, using gradually improving results to enhance the learning outcomes of students. Almost opposite to coping models are mastery models, in which successful performance is demonstrated consistently throughout the task to improve the learners' results. Consequently, it would be interesting to know which condition is most helpful for learning (a condition containing a first negative and second positive picture or a condition containing only positive pictures).

Theories in the Field of Multimedia Learning

The two most well-known theories concerning cognitive support in learning are the cognitive load theory (CLT; Sweller, 1994, 2010) and the cognitive theory of multimedia learning (CTML; Mayer & Mayer, 2005), both of which are based on the postulation that human working memory has a limited capacity and can be overloaded; however, there are some differences between the theories.

Mutlu-Bayraktar et al. (2019) argued that many studies in multimedia learning environments measured cognitive load, especially concerning seductive detail, cueing/signaling, and modality effects. The learning topics in experiments were often STEM (science, technology, engineering, and mathematics) subjects. Sweller (2010) described three different types of cognitive load in CLT: *intrinsic cognitive load* (ICL), *extraneous cognitive load* (ECL), and *germane cognitive load* (GCL). ICL is connected to the complexity of the learning materials that have to be learned; hence, to influence ICL, the learning information itself should be changed. Cognitive processes that are not mandatory for learning and are associated with nonoptimal instructional procedures are employed by ECL; consequently, to improve learning, ECL should be decreased, since emotional overload or distracting emotions can increase the amount of ECL (Plass & Kaplan, 2016). GCL is needed for knowledge building and the integration of new knowledge into prior knowledge. The result of such learning could be a schema—a cognitive construct containing a large amount of organized information (Sweller et al., 1998). Recently, it was discussed if germane cognitive load should belong to basic categories of cognitive load or not (Mutlu-Bayraktar et al., 2019; Sweller et al., 2019).

ICL, ECL, and GCL can also be explained in terms of element interactivity (Sweller, 2010). An element is a unit of material that has to be learned (e.g., a theory, a word, etc.). High element interactivity requires extensive cognitive resources and therefore justifies the use of CLT principles; for example, a schema can be seen as one element that reduces the working memory load and simultaneously allows access to huge amounts of information. This same information may consist of many elements for a learner with low prior knowledge, but only one element for a person with high prior knowledge; therefore, if ECL and ICL are determined mostly by the characteristics of the materials, GCL is associated with the learner's characteristics.

Since cognitive load is assumed to be additive (Sweller et al., 1998), free working memory capacity cannot necessarily be used to increase GCL (see augmented CLT or aCLT; Huk & Ludwigs, 2009). According to aCLT, affective support can increase situational interest and therefore, in combination with cognitive support, increase GCL.

The second important cognitive theory is CTML (Mayer & Mayer, 2005). While CLT uses schema to describe the results of learning, CTML explains how learners select, organize, and integrate information to construct mental models. To improve learning, CTLM suggests using both processing channels (the auditory/verbal channel and the visual/pictorial channel) simultaneously. An example of this could be a graphic presented and explained by a lecturer during a lecture; however, decorative illustrations (without essential information) could distract from learning and lead to an overload of the working memory capacity.

Although CLT and CTML are often applied in the field of multimedia learning, they should be considered critically, since they neglect the roles of affective and motivational processes; therefore, Moreno and Mayer (2007) extended the CTML and developed the cognitive-affective theory of learning with multimedia (CATLM). According to this theory, motivation influences the cognitive process and, in turn, learning outcomes. Furthermore, the ICALM (integrated cognitive-affective model of learning with media) is important, because it interprets the impact of affect on learning with the help of media (Plass & Kaplan, 2016). According to this theory, the processing of information is determined by the reactions of learners to a core affect. Russell (2003) explained that a core affect is a neurophysiological state with two dimensions: arousal (activation-deactivation) and valence (pleasure-displeasure). Both theories, therefore, recommended the inclusion of design elements (e.g., decorative pictures) to influence motivation and emotions.

Decorative Pictures in Learning with Multimedia

Early studies compared decorative (aesthetically appealing) pictures to pictures that included learning information (e.g., Lenzner et al., 2013). Aesthetic perception serves to gratify our senses (Hekkert, 2006). Researchers used different terms for pictures with learning content (instructional pictures, cognitive/helpful/essential illustrations, etc.) and pictures containing different amounts of information; however, they found no benefits of decorative pictures for learning outcomes (Berends & van Lieshout, 2009; Lenzner et al., 2013; Park & Lim, 2007).

Furthermore, Lindner et al. (2021) assumed that only representational pictures—those that illustrate the learned information—improve learning when combined with the texts. They conducted an experiment with representational pictures, which enhanced learning when shown in both the learning and testing phases. Comparably, Hu et al. (2021) conducted a meta-analysis of multimedia effects, describing how people learn better from a combination of text and pictures than from texts alone. They found an effect for representational and organizational pictures, but could not reach a reliable conclusion for decorative pictures. However, Wiley (2019) demonstrated that even pictures that are essential for understanding the learning materials can impede learning, and Sundararajan and Adesope (2020) suggested that the seductive effect was moderated (among other things) by the type of image, delivery format, subject, and recall question category.

Recent multimedia studies reported, in contrast to the seductive detail effect, a positive impact of decorative pictures on learning. Some of them used the term *emotional design* (e.g., Plass & Kaplan, 2016; Schneider et al., 2016) to describe how the inclusion of pleasant elements can influence emotional states and improve learning outcomes (meta-analysis; Brom et al., 2018).

Schneider et al. (2016), for example, showed that positive decorative pictures of people (conducive pictures) enhanced learning. The authors argued that decorative pictures can induce learning-relevant emotions (pretesting pictures' emotional impact as a control) and should be context-related to improve learning performance. Later, Schneider et al. (2018b) demonstrated that decorative pictures in digital environments were useful for learning if the pictures were strongly associated with the learning topic and/or positive; moreover, the learners´ characteristics influenced the learning. Magner, et al. (2014) additionally showed that decorative images improved transfer for participants with high levels of prior knowledge and inhibited learning for students with low levels of prior knowledge. González et al. (2019) explained that learners with low attentional inhibition were negatively affected by decorative pictures. Finally, the learning time in seductive detail experiments was limited (Sitzmann & Johnson, 2014). The approaches of the mentioned theories provide an opportunity to design decorative pictures that might be beneficial, rather than harmful, for learning.

The first question for researchers investigating decorative pictures is which pictures to use. One interesting research topic frequently connected to the study of decorative pictures is that of anthropomorphic pictures (non-human images with human components); for example, Schneider et al. (2018c) demonstrated that both anthropomorphic pictures and personalized labels improved learning performance, motivation, and learners' affect, compared to pictures without such characteristics and a control group (with no decorative pictures); however, a high degree of anthropomorphism was beneficial only for participants with medium levels of prior knowledge (Schneider et al., 2019a). Park et al. (2015) showed that decorative anthropomorphic pictures improved learning, especially for learners with positive emotional states. Furthermore, Shangguan et al. (2020) demonstrated that colorful anthropomorphic pictures promoted transfer only in the second experiment, but not in the first; the difference in the results was explained by the lower level of participants' prior knowledge in the second experiment. Finally, Brom et al. (2018) carried out a meta-analysis and concluded that anthropomorphic pictures and/or the addition of pleasurable colors were beneficial multimedia design principles.

In summary, decorative pictures in digital environments can either improve or impede learning; hence, pictures should be integrated into the learning context, pretested for their emotional impact, and the seductive detail effect should be considered. Furthermore, an important question concerns what should be presented in the pictures: photographs of people or human faces are especially often and successfully used. Finally, the characteristics of the participants should be considered.

The Inclusion of Decorative Pictures in Experiments

Some studies discovered either positive influences (Mikheeva et al. 2021; Schneider et al., 2016, 2018b, 2018c) or negative effects of decorative pictures on learning (Berends & van Lieshout, 2009; Elia & Philippou, 2004). In other studies, decorative pictures had no effects (Lenzner et al., 2013; Park & Lim, 2007) or produced inconsistent results (Magner et al., 2014; Schneider et al. 2020). Other aspects are important for learning with decorative pictures apart from the choice of pictures or the focus of learners.

The number and placement of pictures might explain some differences in the study results; for example, Mikheeva et al. (2021) presented two decorative pictures (either positive or negative) during the online learning of statistics. According to the results, the first positive picture enhanced learning, whereas the second positive picture lowered the cognitive load. In summary, the pictures had only a few influences. Even when the pictures in the experiment were context-related, they appeared only once in each section, separately from the learning materials. According to Chandler and Sweller (1992), the pictures should not be too distant from the related text if they are to build an integrated mental model. Kulhavy et al. (1994) argued that presenting the text before the picture leads to working memory load for learners making text-picture associations. Schneider et al. (2018b, 2020) integrated the learning text with decorative pictures. For Schneider et al. (2018b), the learning text was divided into many sections; therefore, the decorative pictures were presented frequently, in each learning section. For Schneider et al. (2020), decorative pictures were shown together with learning text on learning videos; however, only key points were read in the video and most of the information was audial. The decorative pictures were beneficial for learning only when presented in the learning and testing phases (the *memory cue effect*), and presenting decorative pictures only in learning videos led to a seductive detail effect. Harp and Mayer (1998) illustrated those interesting but irrelevant elements should be introduced only at the end of the learning materials to avoid the seductive detail effect. They attributed the result to an activation of inappropriate prior knowledge.

Additionally, it made a difference whether the studies were carried out in fields where graphical illustrations were usual (e.g., the natural sciences) or not (De Westelinck et al., 2005). In mathematics, graphics, geometric figures, formulas, or photographs of solutions are typical pictures used in textbooks; hence, the influence of irrelevant (decorative) pictures on mathematical learning was investigated recently (e.g., Chiu et al., 2020; Lindner, 2020).

The influence of decorative pictures on mathematical learning remains uncertain. According to Lindner (2020), only representational pictures promoted learning. Another study showed that all types of illustrations (representational, informational, and organizational) enhanced the solving of mathematical tasks, but decorative pictures did not (Elia & Philippou, 2004). Berends and van Lieshout (2009) compared the influence of different types of illustrations (no task information, little task information, and information additional to the text) to a condition without pictures for mathematical learning. All the pictures led to additional cognitive load and hindered the learning outcomes.

By contrast, Chiu et al. (2020) argued that warm colors and round face-like shapes promoted learning for advanced learners of mathematics. Cooper et al. (2018) investigated the roles of diagrams and illustrations (no learning information, but context-relevant) on mathematical learning. While diagrams improved learning, illustrations were beneficial only for learners with strong mathematical abilities. Taken together, more studies concerning the effects of decorative pictures on mathematical learning are needed. Furthermore, according to Kulcsár (2019), university mathematics textbooks lack explanatory and decorative illustrations.

In summary, the number of presented decorative pictures and their placement can play a role in learning within digital environments. Furthermore, the learning domain might influence learning with decorative pictures. Decorative pictures can enhance mathematical learning in some cases; however, the levels of mathematical skill and prior knowledge should also be considered.

The Order of Emotional Pictures

Many experiments used conditions that elicited either positive or negative emotions (e.g., Schneider et al., 2016), but that is not the only possibility: negative and positive pictures can be combined. Coping and mastery models could be an applicable theoretical basis for such options, but the models have typically been formulated almost in contrast to each other (Schunk, 1999). According to mastery models, successful performance should be demonstrated consistently, whereas coping models assume that competence should be demonstrated by gradual improvement during learning tasks to enhance learning outcomes. Numerous studies were carried out to compare these models. However, the results were inconsistent.

Many experiments found no differences between the influences of mastery and coping models; for instance, Schunk and Hanson (1985) carried out a mathematical experiment to investigate the *self-efficacy* (perceived capabilities) of children, but the results indicated no differences between the mastery and coping models. Possibly the children oversaw the differences in the models. Many medical experiments have also been conducted; for example, one study investigated the influences of the models on pedodontic patients' disruptiveness, finding that the demonstration of mastery or coping reduced the patients' disruptiveness; however, no differences between the models were identified (Klorman et al. 1980). Ginther and Roberts (1983) critically considered the work of Klorman et al. (1980), because they did not examine levels of fear. Ginther and Roberts (1983) carried out a similar experiment and reported no differences between the models for children with dental anxiety.

Only one experiment indicated that a mastery model had advantages compared to a coping model. A study by Mikheeva et al. (2021) investigated whether mastery or coping models were beneficial for the online learning of statistics. Their study used pretested, emotionally charged, decorative pictures of a student solving mathematical tasks on a computer. The results showed that the mastery model partially enhanced the learning outcomes and reduced cognitive load; however, there were only a few significant effects, with low or moderate effect size.

Many experiments have shown the benefits of coping models compared to mastery models; for example, by examining how mastery and coping models influenced self-efficacy during exercises performed by patients with COPD (chronic obstructive pulmonary disease) (Selzler et al. 2020). Different models of the exercises were shown on the video, and the coping models revealed different mistakes at the beginning; both models improved self-efficacy, but the coping model was the most helpful. Cunningham et al. (1993) used videos for a parent-training program to compare mastery and coping models, reporting that the number of sessions and the amount of completed homework were increased by the coping model. Meichenbaum (1971) investigated the influence of the models on avoidance behavior, and the coping model proved to be the most effective model for reducing avoidance.

Additionally, some mathematical experiments demonstrated the advantages of coping models compared to mastery models. Schunk et al. (1987) examined the impact that mastery and coping models had on the learning and self-efficacy of children during mathematical exercises and considered the different attributes of peers. In the first experiment, either an opposite- or same-sex peer presented either a coping model with slow progress or a mastery model with rapid success. The results showed that the coping model improved learning and self-efficacy. In the following experiment, the children viewed either one or three same-sex peers presenting mastery or coping models. The mastery models were beneficial only when demonstrated many times. In contrast to mastery models, the coping models were effective even when only shown once. It was possible that the participants identified more closely with coping models and considered themselves to be less successful than the mastery models. Schunk and Hanson (1989) also carried out an experiment similar to the second experiment of Schunk et al. (1987). A condition without negative emotions was included in the coping models. The participants described themselves as less capable than the coping model; however, the coping model improved self-efficacy. In summary, coping models seemed to be the best way to enhance self-efficacy in mathematics; nonetheless, in addition to self-efficacy, the similarity between a participant and a peer could moderate learning. According to Braaksma et al. (2002), weak learners learn better from weak peers and strong learners benefit from cooperation with successful peers.

Taken together, the results of these experiments were contradictory. Most studies were carried out in the fields of medicine or mathematics, but many of these investigations found no differences between the influences of the respective models. Some studies (especially mathematical ones) demonstrated the advantages of coping models compared to mastery models; nevertheless, more studies should be conducted in multimedia learning environments using mastery and coping models.

Research Questions and Hypotheses

This experiment used decorative pictures, showing a female student learning with a computer, to induce negative and positive emotions in a learning context. Despite many studies demonstrating that decorative pictures improve learning, questions remained to be answered.

Most studies use either a negative or a positive picture condition (e.g., Schneider et al., 2016), but what would happen if both negative and positive pictures were displayed in a condition? In coping models, first a negative picture and then a positive one should be shown; however, mastery models assume that a condition with only positive examples is more likely to improve learning (Schunk, 1999). Previous studies manifested the advantages of coping models (Schunk et al., 1987, etc.), but are they relevant to online learning studies?

> *Hypothesis 1:* If the picture in the first section is negative, and that in the second is positive, learning performance is fostered compared to conditions with pictures of different valences.

Decorative pictures are often seen as seductive detail (e.g., Rey, 2012) or as an unnecessary cognitive load (Berends & van Lieshout, 2009). According to Sweller (2010), an optimal design of learning materials should decrease ECL and increase GCL, but ICL should not change.

The influences of the coping/mastery models on cognitive load were not investigated. Since coping models often increased learning outcomes and/or self-efficacy, they might reduce ECL and increase GCL (Schunk et al., 1987):

> *Hypothesis 2:* If the picture in the first section is negative, and that in the second is positive, ECL decreases and the GCL increases compared to conditions with pictures of different valences.

According to ICALM (Plass & Kaplan, 2016) and CATLM (Moreno & Mayer, 2007), there is a need for design elements (e.g., decorative pictures) to influence motivation and emotions and thereby enhance learning; therefore, negative/positive activations and valence should be measured to control the experiment.

Concerning mastery/coping models, there were no differences between models on patients' fear (Ginther & Roberts, 1983; Klorman et al., 1980), but coping models enhanced self-efficacy (Schunk & Hanson, 1989; Schunk et al., 1987; Selzler et al., 2020) or reduced avoidance behavior (Meichenbaum, 1971); thus, coping models should increase valence and positive activation, but decrease negative activation:

> *Hypothesis 3:* If the picture in the first section is negative, and that in the second is positive, positive activation and valence increase, and negative activation decreases, compared to conditions with pictures of different valences.

Finally, the influences of single factors should be investigated. For example, if first/second positive picture increases learning, positive activation and valence and decreases cognitive load and negative activation. According to Schneider et al. (2016) positive valenced pictures promoted learning.

Method

Pretest of Emotional Pictures

To validate the emotional valence of pictures for the experiment, a female student in her mid-twenties with red hair was cast for a photoshoot. A female student was chosen for photos because most of potential participants were young female students and should be able to identify themselves with the photos. The student was instructed to present positive emotions (i.e., relaxation, enjoyment, hope) and negative emotions (i.e., anger, anxiety, boredom), because these emotions were found to be typical learning emotions (Pekrun & Linnenbrink-Garcia, 2014). Before the shoot, the student saw emotional pictures on the internet that were typical for each emotion. The student tried to mimic different emotions. The camera was focused only on the upper part of the student´s body and the computer. What all pictures had in common was that the student was looking at a computer monitor displaying mathematical tasks that she was trying to solve using a pencil and a sheet of paper. While working on the mathematical tasks, the student mimicked different emotions with the upper part of her body. The photos should be similar to the learning situation during the presented experiment, they should be context-related to enhance learning.

Subsequently, 38 sharp, high-quality pictures (8 for each emotion) were chosen for validation. There were 154 participants in the pretest, some of whom were excluded from further analysis because they withdrew from the test at the beginning of the questions. The data of 135 students (72 female, 62 male, 1 with no information) were therefore analyzed. Some of the participants completed only part of the pretest. The age of the participants ranged from 18 to 63 ($M = 24.73$, $SD = 6.29$). Each participant rated all the pictures according to the question: "How does the picture affect you?" Beneath the question, 8 x 7-point scales measuring positive affect ($\alpha = 0.77$) and negative affect ($\alpha = 0.76$) were taken from the PANAVA-KS questionnaire (Schallberger, 2005). Based on the lowest and highest means of all pictures, a negative and a positive picture were chosen. Subsequently, the chosen pictures were statistically analyzed. First, the positive affect scales for both pictures were compared. For positive affect, the positive picture had significantly higher scores ($M = 5.94$, $SD = 1.40$) than the negative picture ($M = 2.37$, $SD = 1.18$), $t(58) = 13.49$, $p < 0.001$, $d = 2.05$. For negative affect, the positive picture had significantly lower scores ($M = 2.82$, $SD = 1.10$) than the negative picture ($M = 3.44$, $SD = 1.14$), $t(58) = -2.82$, $p = 0.007$, $d = 1.70$. The two chosen pictures are shown in Figure 1.

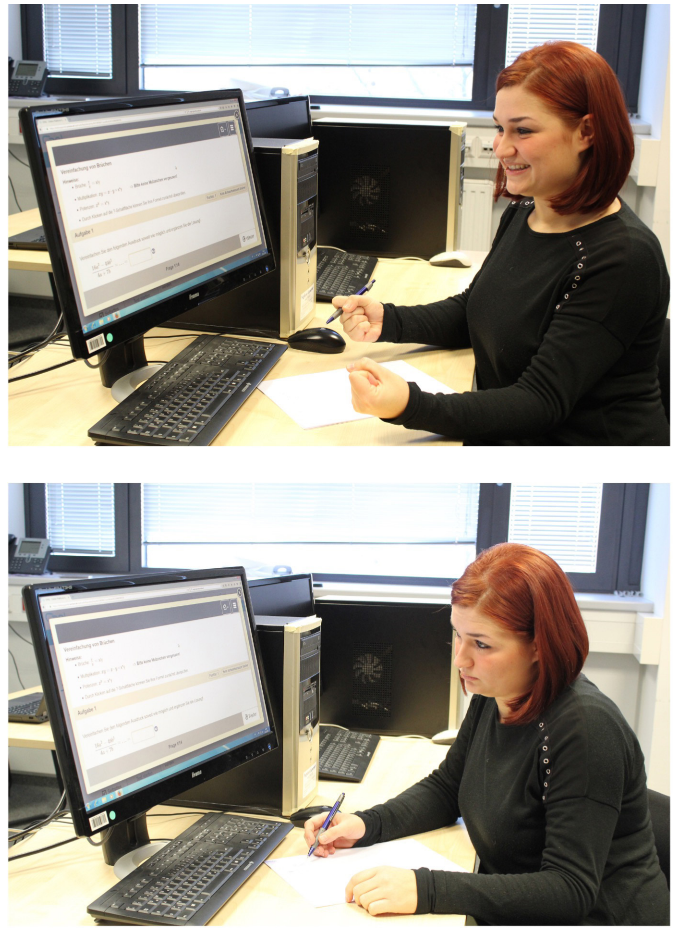

Figure 1. Positive (above) and negative (below) pictures

Participants and Design

According to previous studies, a large effect size could be expected (e.g., Schneider et al., 2018b, 2018c). An a-priori power analysis ($f = .40$; $\alpha = .05$; $1\text{-}\beta = .80$) determined that a minimum of 52 participants would be needed to detect a minimum of a large effect size in a two-factor experiment with two levels per factor.

Ninety-two students (24 male) participated in the experiment. The students were between 18 and 35 years of age ($M = 21.91$, $SD = 3.01$) and from different courses of study: media communication (47%), media and instructional psychology (13%), psychology (14%), and others (26%). There were no significant differences between the four experimental groups in terms of gender, subject, prior knowledge, or age (all $p > 0.05$). The students participated in the experiment in a computer laboratory in return for course credits and all gave their informed consent. The participation was anonymous.

The experiment was divided into two sections, due to the amount of learning information. Each section included four pages with learning information and pictures presented together, emotional questionnaire (PANAVA-KS) items, and tasks relating to the learning information (Figure 3). For an experimental check of the hypotheses, a 2 × 2 between-subjects design was used, employing the factors "picture in the first section" (positive vs. negative), and "picture in the second section" (positive vs.

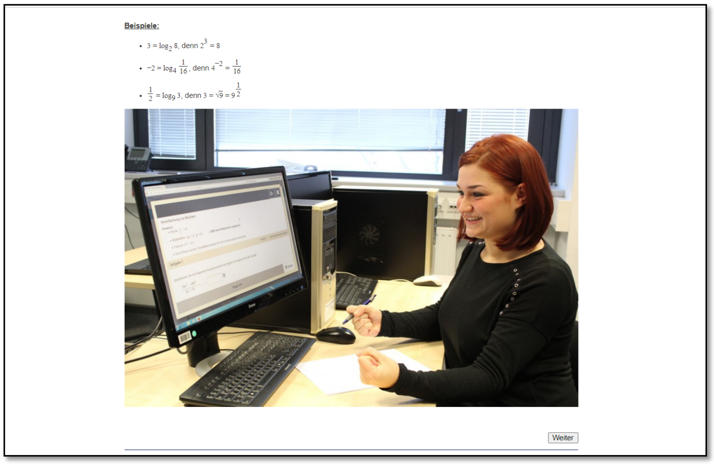

Figure 2. An example of a learning page with a positive decorative picture.

negative). Students were assigned via block randomization to one of four groups: both pictures positive (n = 23); the first picture positive and the second picture negative (n = 23); the first picture negative and the second picture positive (n = 23); and both pictures negative (n = 23).

Materials and Measures

An online questionnaire (https://www.soscisurvey.de) was used for the experiment. The students were allowed to use a pencil and sheets of blank paper. The experiment consisted of a prior knowledge test, the two sections, a cognitive load questionnaire, and demographical questions. Each section had learning information combined with decorative pictures, an emotional questionnaire, and tasks.

The prior knowledge test (α = 0.83) included eight open-ended questions. Students were asked to solve tasks with logarithms; for example, "$\log_{28}4+\log_{28}7$=?" or "$\log_{20}4+\log_{20}5$=?" Two independent raters gave students points for correct answers based on a pre-set schema of correct answers: ICC (1, 2) = 1. In summary, eight points could be gained for the prior knowledge test, with one point given for each correctly solved task.

The experimental manipulation was split into two sections. Each section consisted of four pages with learning information presented with decorative pictures, an emotional questionnaire, and tasks. In the first section, the texts explained logarithms (see Figure 2), presenting explanations and examples, in a few lines per page and totaling 185 words. In the second section, the rules of logarithms were presented, with examples showing how to apply the rules, in a few lines per page and totaling 110 words. Under each portion of learning material, there was a large decorative picture. The picture was much larger than the text and took up about a half of space on the computer display. In each section, the same picture (positive or negative) was shown four times. After their learning, the students had to answer questions. The questions had different formats: single-choice questions and open-ended questions. For each question, either zero or one point could be scored. The first section contained eight questions relating to logarithms (max. eight points). The second section contained nine questions (max. nine points). The Cronbach´s alpha values for both sections were high (α = 0.86). One example of a question is: "For a number a > 0 apply … a) $\log_a a=1$, b) $\log_a a=0$, c) $\log_a a=a$. A further example is: "$\log_{32}8$=?"; "$\log_{10}2+\log_{10}5$=?"

Two additional questionnaires were included in the experiment. First, the PANAVA-KS questionnaire was included, consisting of three dimensions: positive activation, negative activation, and valence (α = 0.70) (Schallberger, 2005). The questionnaire measured the emotional states of the students twice (after learning in each section). Second, a cognitive load questionnaire was displayed, which measured intrinsic (α = 0.87), extraneous (α = 0.79), and germane cognitive load (α = 0.93) (Leppink et al., 2013). This questionnaire was presented after the last question.

Procedure

The experimental procedure is shown in Figure 3. The students were instructed to press the "continue" button on their screens (there was no "back" button). There was always only one task per page. Each section began with a learning text, and a decorative picture was presented below the text, which was larger than the text. In summary, the decorative pictures were shown eight times during the entire experiment. The text was divided into four pages. The time for reading the text was unlimited, but students were not allowed to take notes on the paper. The experiment took approximately one hour, but there were no time limits for the questions. The students participated in the experiment in small groups (less than 10 people, separately from each other) or as individuals.

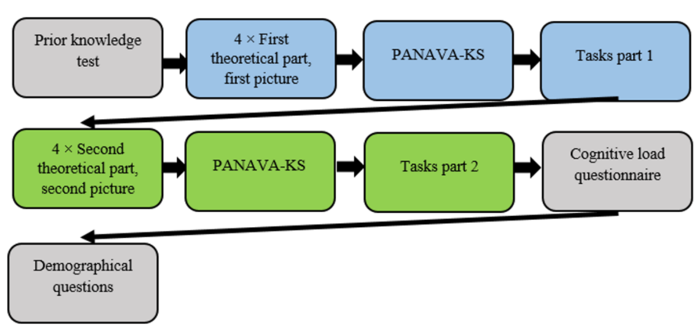

Figure 3. The experimental procedure.
The first section is marked in blue, the second is in green.

Results

The influence of Decorative Pictures on Learning Scores

Univariate analysis of variance (ANOVA) was conducted to check the influence of the valence of the picture in the first section on the learning outcomes in the first section. In the order of the experiment, the learning performance in the first section (tasks part 1) was measured before the second picture was shown.

Table 1. Mean scores on the dependent variables and their corresponding standard deviations for the four experimental groups.

Type of measurement	Experimental condition							
	First positive and second positive pictures (*N* = 23)		First negative and second positive pictures (*N* = 23)		First positive and second negative pictures (*N* = 23)		First negative and second negative pictures (*N* = 23)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
LO in the 1th section	1.87	1.42	2.43	1.95	2.70	2.55	2.74	2.12
LO in the 2th section	4.00	1.73	4.44	1.93	4.13	2.22	4.09	2.07
ICL	7.48	2.24	7.28	2.77	6.68	3.08	7.26	2.77
ECL	4.91	1.91	3.88	2.30	4.88	2.17	4.30	2.19
GCL	4.60	2.40	4.98	2.43	3.95	2.29	4.83	2.80
Positive activation	0.09	1.41	-0.10	0.96	-0.40	0.71	-0.22	0.73
Negative activation	0.08	1.06	0.35	0.86	0.45	0.57	0.19	0.60
Valence	-0.02	1.64	-0.44	1.33	-0.50	1.12	-0.76	1.08

Note. LO = learning outcomes. LO in the first section ranged from 0 to 8 points. LO in the second section ranged from 0 to 9 points. ICL/ECL scores ranged from 0 to 30, and GCL scores ranged from 0 to 40. Positive/negative activation scores ranged from 0 to 28, and valence scores ranged from 0 to 14. The results of the first measure of valence, and negative and positive activations, were subtracted from the results of the second measure of the same variables.

Thus, the second factor (the valence of the second picture) did not influence the learning results of the first section. Consequently, only two groups (first positive picture and first negative picture) were considered. There was no significant difference between the group with the first positive picture and the group with the first negative picture: $F(1, 90) = 0.51$, $p = .478$, $\eta_p^2 = .01$ (see Table 1 for mean scores for the dependent variables and their corresponding standard deviations for the four experimental groups). Therefore, Hypothesis 1 could not be confirmed for the learning outcomes in the first section.

A further ANOVA was conducted for the between-subject factor valence of the picture in the first section and valence of the picture in the second section, with the learning outcomes in the second section as dependent variables. There was no significant main effect for the factor valence of the picture in the first section: $F(1, 88) = 0.22$, $p = .639$, $\eta_p^2 = .003$. No significant main effect existed for the factor valence of the picture in the second section: $F(1, 88) = 0.07$, $p = .794$, $\eta_p^2 = .001$. There was also no significant interaction between the factors: $F(1, 88) = 0.33$, $p = .567$, $\eta_p^2 = .004$. Hypothesis 1 could not be confirmed for the learning outcomes in the second section.

The influence of Decorative Pictures on Cognitive Load

Next, a multivariate analysis of variance (MANOVA) was conducted for the between-subject factor valence of the picture in the first section and the valence of the picture in the second section, with ICL, ECL, and GCL as dependent variables. All predefined test assumptions were met: Box's M (18, 27365.30) = 17.11, $p = .589$. There was no significant main effect for the factor valence of the picture in the first section: Wilks' $\Lambda = .95$, $F(3, 86) = 1.48$, $p = .224$, $\eta_p^2 = .05$. There was no significant main effect for the factor valence of the picture in the second section: Wilks' $\Lambda = .98$, $F(3, 86) = 0.63$, $p = .597$, $\eta_p^2 = .02$. There was no significant interaction between the factors: Wilks' $\Lambda = .98$, $F(3, 86) = 0.66$, $p = .577$, $\eta_p^2 = .02$. Therefore, follow-up ANOVAs were not carried out. Overall, Hypothesis 2 could not be confirmed for cognitive load.

The Influence of Decorative Pictures on Emotions

A further MANOVA was conducted for the between-subject factor valence of the picture in the first section and the picture in the second section, with changes in valence, positive affect, and negative affect as the dependent variables. The results for the first measure of valence, and negative and positive activations, were subtracted from the results for the second measure of the same variables. All predefined test assumptions were met: Box's M (18, 27365.30) = 24.83, p = .180. There was no significant main effect for the factor valence of the picture in the first section: Wilks' Λ = .97, F(3, 86) = 1.04, p = .380, η_p^2 = .04. There was no significant main effect for the factor valence of the picture in the second section: Wilks' Λ = .97, F(3, 86) = 1.01, p = .394, η_p^2 = .03. There was also no significant interaction between the factors: Wilks' Λ = .96, F(3, 86) = 1.30, p = .281, η_p^2 = .04. Therefore, follow-up ANOVAs were not carried out and Hypothesis 3 could not be confirmed for the valence or negative and positive activation.

Discussion

The purpose of this study was to investigate the influence of decorative pictures on learning outcomes and cognitive load for an online mathematical course. The study lasted for approximately one hour and gave students the opportunity to practice logarithms. The design of the study was similar to the experiment of Mikheeva et al. (2021); however, the learning topic and the procedure of the present experiment differed.

For this experiment, decorative pictures within the learning materials neither enhanced nor hindered learning. One possible reason for the decorative pictures having no influence could be that the pictures were overlooked because they were presented under the learning text. Conceivably, the participants ignored the pictures to concentrate better on the learning, since the pictures took up more space than the text. Shangguan et al. (2020) used a similar experiment, combining large decorative pictures with small text passages on the same pages, and showed little influence of the pictures on learning performance (excluding transfer in the second experiment).

Some studies have found a positive influence of decorative pictures (Mikheeva et al., 2021; Schneider et al., 2016; 2018b; 2018c), but they used them differently. For example, in Schneider et al.'s (2016) study, one picture of people (which was different for each condition) was presented many times, but only on the main (navigation) page and not combined with the learning materials. As in the present study, Schneider et al. (2018b, 2018c) presented the decorative pictures directly on the learning pages; however, they displayed photographs of people, animals, food, or painted images (Schneider et al., 2018b) or images of robots (Schneider et al., 2018c). Furthermore, the decorative pictures were presented together with the learning text, but on the right side of the webpage and smaller than the text.

Other studies showed either negative influences of decorative pictures on learning (Berends & van Lieshout, 2009; Elia & Philippou, 2004), no effects (Lenzner et al., 2013; Park & Lim, 2007), or inconsistent results (Magner et al., 2014); therefore, the present study was consistent with the experiments of Lenzner et al. (2013) and Park and Lim (2007). In Park and Lim's (2007) study, a condition with emotional (decorative) pictures was compared to conditions with cognitive (informational) pictures or no pictures. The pictures neither improved learning outcomes nor led to a seductive detail effect. Similar to the present experiment, the authors placed the pictures under the learning text. According to Kulhavy et al. (1994), pictures should be placed before the text to improve recall. Lenzner et al. (2013) found no differences between the influences of instructional (informative) pictures and decorative pictures on learning. As in the present experiment, they used pictures and the text on the same pages.

Another possible reason for the decorative pictures not influencing learning could have been the participants' levels of mathematical ability because learning performance was rather low. According to Chiu et al. (2020) and Cooper et al. (2018), only participants with strong mathematical skills benefited from the display of decorative pictures.

Furthermore, the results of these experiments could not support mastery or coping models. Selzler et al. (2020) showed the benefits of coping models for the self-efficacy of patients with COPD. The authors used both female and male subjects. Moreover, they used coping model videos, not pictures, and the peers made different mistakes at the beginning of the exercises. The present experiment used pictures of a female student and there were only two different pictures for the coping model, showing no gradual development of the situation. For the mastery model, the same picture was presented many times and possibly ignored.

Furthermore, the information and tasks in the first section were basic and logarithms were explained. In the second section, logarithmic rules were presented; therefore, the learning materials became more complicated. As a result, the participants in the condition with the coping model could have become irritated, since the emotions in the pictures changed from negative to positive but the learning information and tasks become more difficult. Notably, the changes in the difficulty levels were minimal. It is problematic in mathematics to compare different topics, so the same topic was used for both learning cycles. Furthermore, new information requires foundational knowledge, and it was necessary to make small increases in the difficulty level to continue the learning process.

Furthermore, a cognitive load questionnaire (Leppink et al., 2013) was used for the measure of ICL, GCL, and ECL, which was presented after the emotional questionnaire (PANAVA-KS) and the tasks in the second section. No cognitive load effects were found in the present study. Previous studies obtained contradictory results about cognitive load. Some studies also showed a negative influence of decorative pictures on cognitive load (e.g., Berends & van Lieshout, 2009), but the authors did not use a cognitive load questionnaire to measure any types of cognitive load; they only discussed the speed and accuracy of the participants concerning CLT. Some studies also obtained inconsistent results (Mikheeva et al., 2021; Schneider et al., 2018c) or showed a positive influence (Schneider et al., 2018b). These studies measured the cognitive load in a similar way to the current experiment.

Furthermore, the study found no influences of pictures on emotions, which contrasted with the results of previous experiments (e.g., Shangguan et al., 2020) and fitted other findings of this study. Taken together, no positive or negative influences of decorative pictures on learning, emotions, or cognitive load were found.

Implications

This experiment has important theoretical implications for research relating to decorative pictures. Early studies with decorative pictures claimed that decorative pictures impeded learning (the seductive detail effect; Rey, 2012) or enhanced learning if the pictures induced positive learning emotions (conducive decorative pictures; Schneider et al., 2016). This study demonstrated no influences of decorative pictures on learning; therefore, these results expand the theoretical literature. Possibly, the placement or number of presented pictures should have been considered.

The investigation also contributes to discussions about whether coping or mastery models are most helpful in different situations (e.g., Ginther & Roberts, 1983). The findings of this experiment showed no differences between models, possibly because the participants could not associate themselves with one particular model; however, further studies of coping and mastery models in digital learning environments should be conducted.

The investigation has practical implications. First, mathematical online courses may use decorative pictures, because they have no detrimental effect for learning. Second, for mathematical teaching in universities, decorative pictures could be used in the presentations of university teachers. Finally, publishers of mathematical books should consider this study and use decorative pictures, if necessary.

Limitations

The manipulation check failed, and the reason for this could be the use of the pictures under the learning materials on the same pages, meaning that the pictures could be overlooked. There are some further limitations to the study. First, the questions had different levels of difficulty, suggesting that the difficulty level of the questions should have been evaluated before the experiment was conducted. Second, the students should perhaps have been divided into groups according to their mathematical skills. Third, the motivation of students was not measured and controlled for. Furthermore, the experiment was carried out only with students; hence, the results for other age groups could be different, with students remembering the solving of logarithmic tasks at school better than older people. Moreover, the age of the person shown in the decorative pictures could have influenced younger and older participants differently, because they possibly did not identify with the person in the pictures. Finally, the gender of the person in the pictures could have influenced the results. Since only a few men participated in the study, the men's results could not be analyzed separately from those of the women.

Future Directions

This study demonstrated that decorative pictures did not influence the learning of mathematics, but further investigations are required; for example, new studies in the field of multimedia learning could display many different pictures to show a gradual improvement in coping models, possibly also using animation or videos.

Not only the influences of coping and mastery models on learning, cognitive load, and emotions are important to investigate. As previous studies showed, the models can also influence further variables, such as self-efficacy (Schunk & Hanson, 1989; Schunk et al., 1987) or avoidance behavior (Meichenbaum, 1971); therefore, it is important to examine further influences of coping and mastery models, (e.g., influences on the motivation or self-efficacy of participants after the experiment).

There are many opportunities for the design of decorative pictures (of people, food, etc.) and where and how they should be applied in experiments (Harp & Mayer, 1998; Schneider, et al., 2016, 2018b, 2018c). Furthermore, the size of the decorative pictures could vary as well as the relative sizes of the pictures and learning text. New experiments should be designed to investigate the best ways to present decorative pictures.

Furthermore, future studies regarding decorative pictures should consider the differences between participants in terms of their motivation before the experiment, their results achieved during the experiment, their previous knowledge, and their identification with peers during the experiment. Peers of different ages, with different nationalities and sex, could be used. Moreover, studies should introduce control conditions (i.e., with no pictures) and experiments should be conducted in different fields (besides mathematics).

References

Berends, I. E., & Van Lieshout, E. C. (2009). The effect of illustrations in arithmetic problem-solving: Effects of increased cognitive load. *Learning and Instruction, 19*(4), 345–353. https://doi.org/10.1016/j.learninstruc.2008.06.012

Braaksma, M. A., Rijlaarsdam, G., & Van den Bergh, H. (2002). Observational learning and the effects of model-observer similarity. *Journal of Educational Psychology, 94*(2), 405–415. https://doi.org/10.1037/0022-0663.94.2.405

Brom, C., Stárková, T., & D'Mello, S. K. (2018). How effective is emotional design? A meta-analysis on facial anthropomorphisms and pleasant colors during multimedia learning. *Educational Research Review, 25,* 100–119. https://doi.org/10.1016/j.edurev.2018.09.004

Carney, R. N., & Levin, J. R. (2002). Pictorial illustrations still improve students' learning from text. *Educational Psychology Review, 14*(1), 5–26. https://link.springer.com/article/10.1023/A:1013176309260

Chandler, P., & Sweller, J. (1992). The split-attention effect as a factor in the design of instruction. *British Journal of Educational Psychology, 62*(2), 233–246. https://doi.org/10.1111/j.2044-8279.1992.tb01017.x

Chiu, T. K., Jong, M. S. Y., & Mok, I. A. (2020). Does learner expertise matter when designing emotional multimedia for learners of primary school mathematics? *ETR&D-Educational Technology Research and Development, 68*(5), 2305–2320. https://doi.org/10.1007/s11423-020-09775-4

Cooper, J. L., Sidney, P. G., & Alibali, M. W. (2018). Who benefits from diagrams and illustrations in math problems? Ability and attitudes matter. *Applied Cognitive Psychology, 32*(1), 24–38. https://doi.org/10.1002/acp.3371

Cunningham, C. E., Davis, J. R., Bremner, R., Dunn, K. W., & Rzasa, T. (1993). Coping modeling problem solving versus mastery modeling: effects on adherence, in-session process, and skill acquisition in a residential parent-training program. *Journal of Consulting and Clinical Psychology, 61*(5), 871–877. https://doi.org/10.1037/0022-006X.61.5.871

De Westelinck, K., Valcke, M., De Craene, B., & Kirschner, P. (2005). Multimedia learning in social sciences: Limitations of external graphical representations. *Computers in Human Behavior, 21*(4), 555–573. https://doi.org/10.1016/j.chb.2004.10.030

Elia, I., & Philippou, G. (2004). The functions of pictures in problem solving. In M. J. Høines & A. B. Fuglestad (Eds.), *Proceedings of the 28th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 327–334), Bergen University College. https://files.eric.ed.gov/fulltext/ED489736.pdf

Ginns, P. (2005). Meta-analysis of the modality effect. *Learning and Instruction, 15*(4), 313–331. https://doi.org/10.1016/j.learninstruc.2005.07.001

Ginther, L. J., & Roberts, M. C. (1983). A test of mastery versus coping modeling in the reduction of children's dental fears. *Child & Family Behavior Therapy, 4*(4), 41–52. https://doi.org/10.1300/J019v04n04_04

González, F. M., Saux, G., & Burin, D. (2019). The decorative images' seductive effect in e-learning depends on attentional inhibition. *Australasian Journal of Educational Technology, 35*(3), 166–178. https://doi.org/10.14742/ajet.4577

Harp, S. F., & Mayer, R. E. (1998). How seductive details do their damage: A theory of cognitive interest in science learning. *Journal of Educational Psychology, 90*(3), 414–434. https://doi.org/10.1037/0022-0663.90.3.414

Hekkert, P. (2006). Design aesthetics: principles of pleasure in design. *Psychology Science, 48*(2), 157–172. https://www.wiso-net.de/document/PSS__b69867e8389c427dda625eff896bafa6d4300684

Hu, L., Chen, G., Li, P., & Huang, J. (2021). Multimedia effect in problem solving: A meta-analysis. *Educational Psychology Review.* https://doi.org/10.1007/s10648-021-09610-z

Huk, T., & Ludwigs, S. (2009). Combining cognitive and affective support in order to promote learning. *Learning and Instruction, 19*(6), 495–505. https://doi.org/10.1016/j.learninstruc.2008.09.001

Klorman, R., Hilpert, P. L., Michael, R., LaGana, C., & Sveen, O. B. (1980). Effects of coping and mastery modeling on experienced and inexperienced pedodontic patients' disruptiveness. *Behavior Therapy, 11*(2), 156–168. https://doi.org/10.1016/S0005-7894(80)80016-5

Kulcsár, N. (2019). Visuals versus textual elements in university mathematics textbooks. In L. Gómez Chova, A. López Martínez, & I. Candel Torres (Eds.), *EDULEARN19 Proceedings* (pp. 4289–4294), IATED Academy. http://doi.org/10.21125/edulearn.2019.1083

Kulhavy, R. W., Stock, W. A., & Caterino, L. C. (1994). Reference maps as a framework for remembering text. In W. Schnotz & R. W. Kulhavy (Eds.), *Comprehension of graphics* (pp. 153–162). Elsevier. https://doi.org/10.1016/S0166-4115(09)60114-X

Lenzner, A., Schnotz, W., & Müller, A. (2013). The role of decorative pictures in learning. *Instructional Science, 41*(5), 811–831. https://doi.org/10.1007/s11251-012-9256-z

Leppink, J., Paas, F., Van der Vleuten, C. P. M., Van Gog, T., & Van Merriënboer, J. J. G. (2013). Development of an instrument for measuring different types of cognitive load. *Behavior Research Methods, 45*(4), 1058–1072. https://doi.org/10.3758/s13428-013-0334-1

Lindner, M. A. (2020). Representational and decorative pictures in science and mathematics tests: Do they make a difference? *Learning and Instruction, 68*, 1–11. https://doi.org/10.1016/j.learninstruc.2020.101345

Lindner, M. A., Eitel, A., Barenthien, J., & Köller, O. (2021). An integrative study on learning and testing with multimedia: Effects on students' performance and metacognition. *Learning and Instruction, 71,* Article 101100. https://doi.org/10.1016/j.learninstruc.2018.01.002

Magner, U. I., Schwonke, R., Aleven, V., Popescu, O., & Renkl, A. (2014). Triggering situational interest by decorative illustrations both fosters and hinders learning in computer-based learning environments. *Learning and Instruction, 29,* 141–152. https://doi.org/10.1016/j.learninstruc.2012.07.002

Mayer, R., & Mayer, R. E. (Eds.). (2005). *The Cambridge handbook of multimedia learning*. Cambridge university press.

Meichenbaum, D. H. (1971). Examination of model characteristics in reducing avoidance behavior. *Journal of Personality and Social Psychology, 17*(3), 298–307. https://doi.org/10.1037/h0030593

Mikheeva, M., Schneider, S., Beege, M., & Rey, G. D. (2019). Boundary conditions of the politeness effect in online mathematical learning. *Computers in Human Behavior, 92,* 419–427. https://doi.org/10.1016/j.chb.2018.11.028

Mikheeva, M., Schneider, S., Beege M., & Rey, G.D. (2021). The influence of affective decorative pictures on learning statistics online. *Human Behavior and Emerging Technologies,* 1–12. https://doi.org/10.1002/hbe2.250

Moreno, R., & Mayer, R. (2007). Interactive multimodal learning environments. *Educational Psychology Review, 19*(3), 309–326. https://doi.org/10.1007/s10648-007-9047-2

Mutlu-Bayraktar, D., Cosgun, V., & Altan, T. (2019). Cognitive load in multimedia learning environments: A systematic review. *Computers & Education, 141,* 1–22. https://doi.org/10.1016/j.compedu.2019.103618

Park, B., Knörzer, L., Plass, J. L., & Brünken, R. (2015). Emotional design and positive emotions in multimedia learning: An eyetracking study on the use of anthomorphisms. *Computers & Education*, *86,* 30–42. https://doi.org/10.1016/j.compedu.2015.02.016

Park, S., & Lim, J. (2007). Promoting positive emotion in multimedia learning using visual illustrations. *Journal of Educational Multimedia and Hypermedia, 16*(2), 141–162. https://www.learntechlib.org/primary/p/21781/

Pekrun, R., & Linnenbrink-Garcia, L. (Eds.). (2014). *International handbook of emotions in education*. Routledge.

Plass, J. L., & Kaplan, U. (2016). Emotional design in digital media for learning. In S. Tettegah & M. Gartmeier (Eds.), *Emotions, technology, design, and learning* (pp. 131–162). Elsevier.

Rey, G. D. (2012). A review of research and a meta-analysis of the seductive detail effect. *Educational Research Review, 7*(3), 216–237. https://doi.org/10.1016/j.edurev.2012.05.003

Rop, G., van Wermeskerken, M., de Nooijer, J. A., Verkoeijen, P. P., & van Gog, T. (2018). Task experience as a boundary condition for the negative effects of irrelevant information on learning. *Educational Psychology Review, 30*(1), 229–253. https://doi.org/10.1007/s10648-016-9388-9

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review, 110*(1), 145–172. https://doi.

org/10.1037/0033-295X.110.1.145

Schallberger, U. (2005). *Kurzskalen zur Erfassung der Positiven Aktivierung, Negativen Aktivierung und Valenz in Experience Sampling-Studien (PANAVA-KS). Forschungsberichte aus dem Projekt: "Qualität des Erlebens in Arbeit und Freizeit", Nr. 6* [Short scales to measure the positive activation, negative activation, and valence in experience sampling studies (PANAVA-KS). Research report from the project: "Quality of experiences in work and leisure time", no. 6]. Psychologisches Institut der Universität Zürich, Fachrichtung Angewandte Psychologie.

Schneider, S., Beege, M., Nebel, S., & Rey, G. D. (2018a). A meta-analysis of how signaling affects learning with media. *Educational Research Review, 23,* 1–24. https://doi.org/10.1016/j.edurev.2017.11.001

Schneider, S., Dyrna, J., Meier, L., Beege, M., & Rey, G. D. (2018b). How affective charge and text–picture connectedness moderate the impact of decorative pictures on multimedia learning. *Journal of Educational Psychology, 110*(2), 233–249. https://doi.org/10.1037/edu0000209

Schneider, S., Häßler, A., Habermeyer, T., Beege, M., & Rey, G. D. (2019a). The more human, the higher the performance? Examining the effects of anthropomorphism on learning with media. *Journal of Educational Psychology, 111*(1), 57–72. https://doi.org/10.1037/edu0000273

Schneider, S., Nebel, S., Beege, M., & Rey, G. D. (2018c). Anthropomorphism in decorative pictures: Benefit or harm for learning? *Journal of Educational Psychology, 110*(2), 218–232. https://doi.org/10.1037/edu0000207

Schneider, S., Nebel, S., Beege, M., & Rey, G. D. (2020). The retrieval-enhancing effects of decorative pictures as memory cues in multimedia learning videos and subsequent performance tests. *Journal of Educational Psychology, 112*(6), 1111–1127. https://doi.org/10.1037/edu0000432

Schneider, S., Nebel, S., & Rey, G. D. (2016). Decorative pictures and emotional design in multimedia learning. *Learning and Instruction, 44,* 65–73. https://doi.org/10.1016/j.learninstruc.2016.03.002

Schneider, S., Wirzberger, M., & Rey, G. D. (2019b). The moderating role of arousal on the seductive detail effect in a multimedia learning setting. *Applied Cognitive Psychology, 33*(1), 71–84. https://doi.org/10.1002/acp.3473

Schunk, D. H. (1999). Social-self interaction and achievement behavior. *Educational Psychologist, 34*(4), 219–227. https://doi.org/10.1207/s15326985ep3404_3

Schunk, D. H., & Hanson, A. R. (1985). Peer models: Influence on children's self-efficacy and achievement. *Journal of Educational Psychology, 77*(3), 313–322. https://doi.org/10.1037/0022-0663.77.3.313

Schunk, D. H., & Hanson, A. R. (1989). Influence of peer-model attributes on children's beliefs and learning. *Journal of Educational Psychology, 81*(3), 431–434. https://doi.org/10.1037/0022-0663.81.3.431

Schunk, D. H., Hanson, A. R., & Cox, P. D. (1987). Peer-model attributes and children's achievement behaviors. *Journal of Educational Psychology, 79*(1), 54–61.

Selzler, A. M., Rodgers, W. M., Berry, T. R., & Stickland, M. K. (2020). Coping versus mastery modeling intervention to enhance self-efficacy for exercise in patients with COPD. *Behavioral Medicine, 46*(1), 63–74. https://doi.org/10.1080/08964289.2018.1561411

Shangguan, C., Wang, Z., Gong, S., Guo, Y., & Xu, S. (2020). More attractive or more interactive? The effects of multi-leveled emotional design on middle school students' multimedia learning. *Frontiers in Psychology, 10*. https://doi.org/10.3389/fpsyg.2019.03065

Sitzmann, T., & Johnson, S. (2014). The paradox of seduction by irrelevant details: How irrelevant information helps and hinders self-regulated learning. *Learning and Individual Differences, 34,* 1–11. https://doi.org/10.1016/j.lindif.2014.05.009

Sundararajan, N., Adesope, O. (2020). Keep it coherent: A meta-analysis of the seductive details effect. *Educational Psychology Review, 32,* 707–734. https://doi.org/10.1007/s10648-020-09522-4

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*(4), 295–312. https://doi.org/10.1016/0959-4752(94)90003-5

Sweller, J. (2010). Element interactivity and intrinsic, extraneous and germane cognitive load. *Educational Psychology Review, 22*(2), 123–138. https://doi.org/10.1007/s10648-010-9128-5

Sweller, J., Ayres, P., & Kalyuga, S. (2011). Measuring cognitive load. In J. Sweller, P. Ayres, & S. Kalyuga (Eds.), *Cognitive load theory* (pp. 71–85). Springer.

Sweller, J., van Merriënboer, J. J., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), 251–296. https://doi.org/10.1023/A:1022193728205

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review, 31*(2), 261–292. https://doi.org/10.1007/s10648-019-09465-5

Ter Vrugte, J., de Jong, T., Vandercruysse, S., Wouters, P., van Oostendorp, H., & Elen, J. (2017). Computer game-based mathematics education: Embedded faded worked examples facilitate knowledge acquisition. *Learning and Instruction, 50,* 44–53. https://doi.org/10.1016/j.learninstruc.2016.11.007

Wiley, J. (2019). Picture this! Effects of photographs, diagrams, animations, and sketching on learning and beliefs about learning from a geoscience text. *Applied Cognitive Psychology, 33*(1), 9–19. https://doi.org/10.1002/acp.3495

Received: 12.10.2020
Revised: 3.22.2021
Accepted: 3.23.2021