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## Proceedings of the Annual Meeting of the Cognitive Science Society

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Peer reviewed

# Effects of Objects' "Embodiment" on the Acquisition of Problem-Solving Skills through Practice or Video-based Modeling Example Study

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## Abstract

We investigated whether "embodiment" of objects used in a problem-solving task (i.e., whether they have a bodily shape) would have a detrimental effect on learning to solve that problem through practice or through studying video-based modeling examples. A 2x2 design with factors Training (Practice/Example study) and Embodiment (Present/Absent) was used ($N = 80$). Results showed a large main effect of Training on effort investment in learning and on retention test performance, with Example study leading to higher scores with lower investment of effort during the learning phase than Practice. Numerically, Embodiment seemed to have an effect, with participants practicing/studying the task with embodied objects (plastic animals) performing worse on retention than participants practicing/ studying with non-embodied objects (discs), but this did not reach statistical significance. A new study with more power and an additional control condition is currently being conducted and results are expected to be available well before the conference.

**Keywords:** problem solving; example study; embodiment.

## Introduction

A substantial body of research in cognitive science has investigated the effects of a problem's appearance on the acquisition of problem-solving skills. For instance, versions of the Tower of Hanoi task that had the exact same problem space but instead of discs, featured monsters passing globes, or acrobats jumping on each other's shoulders, were found to be much more difficult (Kotovsky, Hayes, & Simon, 1985; see also findings by Goldstone & Son, 2005, on effects of concrete vs. idealized object appearance on pattern learning from a simulation). The present study investigated whether the "embodiment" of objects featured in a problem, that is, whether the objects have a bodily shape, would have a detrimental effect on learning to solve a problem either by means of practice or by means of studying digital video-based modeling examples. To the best of our knowledge, the effects of problem appearance on acquiring problem-solving skills from examples has never been investigated yet.

## Practice vs. Example Study

For students who need to acquire problem-solving skills but lack prior knowledge of a task, practicing with problem solving is not the most efficient way to acquire those skills. It is far more effective and efficient for novice learners to study examples in which the solution procedure is worked-out (worked examples) or demonstrated to the learner (modeling examples; for reviews, see Atkinson, Derry, Renkl, & Wortham, 2000; Renkl, 2011; Sweller, Van Merriënboer, & Paas, 1998; Van Gog & Rummel, 2010). Interestingly, the higher effectiveness and efficiency of example study (possibly alternated with problem-solving) compared to problem-solving practice has not only been found when problems contain no guidance whatsoever, but also when they are tutored problems, on which feedback and hints are provided when errors are made (Salden, Koedinger, Renkl, Aleven, & McLaren, 2010).

Cognitive load theory explains these beneficial effects of example study compared to problem solving in terms of the underlying cognitive processes and associated cognitive load (Sweller et al., 1998). Problems usually contain only a description of some "givens" and a goal statement, without providing any information on how to move from the givens to the goal state. As a consequence, novices have to figure out the correct solution steps to use by themselves, and often do so by resorting to weak problem-solving strategies such as trial-and-error, or means-ends analysis, which impose a high cognitive load but are not very effective for learning: even though such weak strategies may allow learners to succeed in solving the problem eventually (i.e., good performance), they have been shown to contribute

very little to learning (i.e., good performance of that task at a later moment; Sweller, 1988).

Worked examples prevent the use of such weak problem-solving strategies, by presenting the learner not only with the givens and a goal statement, but also with the worked-out solution steps that are to be taken to reach the goal state. The learner can devote all of his or her available cognitive capacity to studying the given solution and constructing a cognitive schema for solving such problems, which can be applied to solve this (or a isomorphic) problem in the future. As such, compared to instruction consisting of problem-solving practice, instruction that relies more heavily on studying worked examples reduces ineffective cognitive load on working memory, and leads to enhanced learning outcomes and often to improved transfer performance (Sweller et al., 1998).

In addition to being more effective for learning, a heavier reliance on examples has also been shown to have beneficial effects on required acquisition time (i.e., lower; see e.g., Sweller & Cooper, 1985; Van Gog, Paas, & Van Merriënboer, 2006; Zhu & Simon, 1987) and cognitive load experienced by students during acquisition (i.e., lower; see e.g., Paas & Van Merriënboer, 1994; Van Gog et al., 2006) as well as during the test (i.e., lower; see e.g., Paas, 1992; Paas & Van Merriënboer, 1994).

However, it should be kept in mind that the beneficial effects of worked examples on learning, acquisition time, and cognitive load, seem to apply primarily to novice learners (for advanced learners, an 'expertise reversal effect' occurs, and problem solving becomes more effective; Kalyuga, Chandler, Tuovinen, & Sweller, 2001; see also Kalyuga, Ayres, Chandler, & Sweller, 2003), and apply only when the examples are well-designed. That is, following early studies on the worked example effect (Cooper & Sweller, 1987; Sweller & Cooper, 1985) it was soon discovered that studying worked examples was not always more effective for learning than problem solving. Rather, the design of the examples played a crucial role in their effectiveness (Tarmizi & Sweller, 1988). For instance, examples that induced split-attention (Chandler & Sweller, 1991; Tarmizi & Sweller, 1988) or included redundant information (Chandler & Sweller, 1991), did not have beneficial effects on cognitive load and learning.

The present study also addresses the effects of problem and example design on cognitive load and learning, though in a very different manner, that is, by investigating the effects of embodiment of the objects used in the task.

## Problem-solving Task and Design Effects

The task used in this study is based on a computer-based problem-solving task called Frog Leap (see Van Gog, 2011; Van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009). In this computer-based task, the goal is to switch the sides of three brown frogs on the right and three green frogs on the left by clicking on them. There is an empty space in the middle. The frogs face in the direction of their goal. If they are clicked on they jump one place ahead or jump over one other frog (they cannot jump over two others, and they cannot go back). The problem can be solved in only one way, in 15 moves.

Prior research has shown the superiority of studying modeling examples (consisting of screen-recordings) over problem solving with this computer-based task. Van Gog et al. (2009) showed that none of the 11 participants in the problem-solving condition managed to solve the problem after practicing twice, and Van Gog (2011) reported pilot data with 7 participants showing the same result even after four practice attempts. In contrast, after studying two examples, the numbers of participants to successfully solve the problem was approximately 58% (Van Gog et al., 2009), and the number of moves correctly completed was approximately 10 (out of 15; Van Gog, 2011). Effects on transfer were not really explored in these prior studies. A second test task was included on which participants had to start on the opposite side as in the example, which was more difficult because the task had not been practiced or studied starting from this side. Therefore, participants could not simply copy the procedure they had learned, and performance on this second test task was lower than on the first (Van Gog, 2011). However, an even stronger transfer test would be to add an additional component on each side, in which case the solution procedure still relies on the same mechanism, but consists of 24 steps and can only be successfully performed when the mechanism is understood.

A closer look at the task suggests that the errors made during problem solving (both during practice and on the test) seem to result from a failure to carefully consider all possible moves and their consequences. This would explain why test performance strongly improved when participants had the chance to study a video-based modeling example twice, in which the procedure was demonstrated (Van Gog, 2011) or demonstrated and explained (Van Gog et al., 2009).

Based on anecdotal evidence of some participants' responses to the task in prior studies, we began to wonder whether this failure to consider all possible moves could be related to the fact that the objects had a bodily shape, that is, were frogs that had a face and "were headed in a direction". That characteristic seemed to evoke anthropomorphic thinking in some participants (i.e., assigning intentions or goals to the frogs; for a discussion of anthropomorphic thinking, see Epley, Waytz, & Cacioppo, 2007). Assigning intentions to the objects that need to be moved, might aggravate the tendency to rapidly execute steps that seem to physically reduce the distance of a frog to its goal, without considering the other possible moves (cf. Sweller & Levine's, 1982, maze learning experiment, in which people who had their left hand on the finish and had to move their right index finger through the maze to get to the finish, continuously made incorrect moves to the left, where they knew their goal was).

If this indeed plays a role, then using the same task but with non-embodied objects should lead to better learning outcomes. To investigate this question, we re-created the

computer-based problem-solving task with real objects, that were either "embodied" (i.e., animals) or "non-embodied" (i.e., discs).

## Hypotheses

Based on prior research on example-based learning in general (for reviews, Atkinson et al., 2000; Renkl, 2011; Sweller et al., 1998; Van Gog & Rummel, 2010), and on the computer-based version of this task in particular (Van Gog, 2011; Van Gog et al., 2009), we first of all expected that studying digital video-based modeling examples would also be more effective (result in higher learning outcomes) as well as more efficient (higher learning outcomes attained with less investment of mental effort) than problem-solving practice for this real object version of the task. The open question of whether performance on a transfer task would also be enhanced when an additional object is added on each side, is explored.

Secondly, it was hypothesized that practicing the problem-solving task with "embodied" objects (i.e. animals) would lead to lower performance than doing so with "non-embodied" objects (i.e., discs). The open question of whether this would only be the case for the problem-solving practice conditions (cf. Kotovsky et al., 1985), or also for the examples conditions, was explored. On the one hand, when studying examples and subsequently taking a test with embodied objects, this might not have negative effects on test performance because participants had a chance to learn the correct procedure from the examples. On the other hand, however, participants might still be affected by the objects' embodiment (e.g., fall prey to anthropomorphic thinking) once they start performing the test task themselves.

## Method

### Participants

Participants were 80 adults (M = 22.8, SD = 2.61; 43 women) recruited from the general population. A 2 x 2 design with factors Training (Practice vs. Example) and Embodiment (Present vs. Absent) was used. Participants were assigned to one of the four conditions matched for gender, but otherwise randomly: (1) Embodiment Present – Practice ($n$ = 20), (2) Embodiment Absent – Practice ($n$ = 20), (3) Embodiment Present – Example ($n$ = 21), and (4) Embodiment Absent – Example ($n$ = 19).

### Materials

**Demographic questionnaire** A demographic questionnaire asked for age, gender, level of education, and it also included a check on whether participants were familiar with the learning task (by showing them a picture of the initial state of the problem in the computer-based version discussed above).

Learning task The learning task was based on the computer-based problem-solving task mentioned above (see Van Gog, 2011; Van Gog et al., 2009). In this computer-

based task, three green frogs are sitting on stones on one side of the river, three brown frogs on the other side, with one empty stone in the middle. The goal is to have them switch sides, but frogs can only jump one place ahead if that is free, or jump over one other frog to a free place. They cannot go back or jump over two other frogs. The goal can be reached in 15 steps. In this study, a version of the task was created using real objects (see Figure 1), and the objects consisted either of plastic yellow fishes and green seals (Embodiment Present) or yellow and green discs (Embodiment Absent).

In the practice conditions, participants were given two practice opportunities in which they attempted to solve the problem for 1 min.; if they got stuck, they were allowed to start again. In the examples conditions, participants observed a digital video-based modeling example (1 min. duration) twice, in which a human model demonstrated the correct solution procedure with either the animal objects or the discs. The model did not provide any verbal explanations and only the model's hand moving the objects was visible in the video. The digital video was presented on a laptop with a screen resolution of 1280 x 720 pixels at a size of 28.5 x 18 cm.
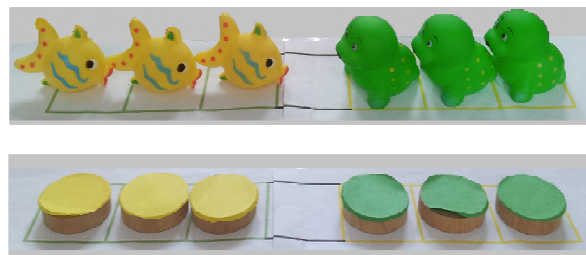


Figure 1: Initial state of the problem in the Embodiment Present (top) and Absent (bottom) conditions

**Test tasks** The retention test task was identical to the learning task. The transfer test task consisted of the same problem, but with four objects on either side. This task could be solved in 24 steps.

**Mental effort** After each practice task, each example, and each test task, participants rated how much effort they invested in problem solving or example study on Paas' (1992) 9-point rating scale ranging from (1) very, very low effort, to (9) very, very high effort. This subjective rating scale is widely used in educational research (for reviews, see Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Van Gog & Paas, 2008).

### Procedure

The study was conducted in individual sessions of approximately 10 min. After filling out the demographic questionnaire, the learning phase started. Participants were first instructed about the rules of the task (i.e., an object can only move one space ahead to a free space or over one other object to a free space, moving back or moving over two other objects is not allowed). Depending on their assigned

condition, they subsequently received the instruction to either practice for 1 min., during which they were allowed to start again if they got stuck, or to study the example presented in the video. After practicing or example study, they rated how much effort they invested in problem solving or example study. Then this sequence was repeated a second time. Depending on their assigned condition, participants practiced with either animals or discs or observed a modeling example with either animals or discs. Immediately after the learning phase, the test phase started, during which all participants were required to solve the problem themselves, first the retention task, which was the exact same problem they had encountered in the learning phase, with three objects on both sides, then the transfer task with four objects on both sides. Depending on their assigned condition, participants performed the test tasks with either animals (when they had practiced/studied the task with animals) or discs (when they had practiced/studied the task with discs). Immediately after each task, they indicated how much effort they invested in attempting to solve the problem. In the test phase, participants' performance was recorded on digital video (zooming in on their hands and the task), to be able to score their performance afterwards.

## Data analysis

Using the video recordings, each participant's performance on the test tasks was determined by scoring the number of steps correctly executed. For the first test task, this resulted in a maximum score of 15, for the transfer task, in a maximum score of 24. For two participants, performance scores were lost due to a technical recording error and two participants failed to fill out an effort rating. Because initial explorative analyses showed that the performance on the test tasks was not normally distributed, a log transformation was conducted (Field, 2009).

## Results

Data were analyzed using 2 x 2 ANOVAs with between-subjects factors Training (Practice vs. Example) and Embodiment (Present vs. Absent). For all analyses a significance level of .05 was used and Cohen's $d$ is reported as a measure of effect size, with 0.20, 0.50, and 0.80 constituting small, medium, and large effects, respectively.

### Effort Invested in the Learning Phase

There was a significant main effect of Training on mental effort invested in the learning phase $F(1,74) = 102.09$, $MSE = 3.08$, $p < .001$, Cohen's $d = 2.31$, with participants who studied the video-based modeling examples reporting much lower effort ($M = 2.94$, $SD = 1.63$) than participants who practiced problem solving ($M = 7.00$, $SD = 1.87$). There was no significant main effect of Embodiment, nor a significant interaction effect.

### Retention Test Task

There was a significant main effect of Training, $F(1,74) = 15.09$, $MSE = .07$, $p < .001$, Cohen's $d = 0.87$, which indicated that participants in the Example conditions outperformed ($M = 0.79$, $SD = 0.30$; non-transformed: $M = 6.74$, $SD = 5.44$) participants in the practice conditions ($M = 0.56$, $SD = 0.22$; non-transformed: $M = 3.13$, $SD = 2.49$). Although there was a trend towards an effect of Embodiment, with participants in the Embodiment Absent conditions performing better ($M = 0.72$, $SD = 0.29$; non-transformed: $M = 5.51$, $SD = 4.78$) than participants in the Embodiment Present conditions ($M = 0.63$, $SD = 0.28$; non-transformed: $M = 4.36$, $SD = 4.36$) this did not reach significance, $F(1,74) = 2.35$, $MSE = .068$, $p = 0.129$, Cohen's $d = 0.30$. There was no significant interaction.

A 2 x 2 ANOVA on invested mental effort on the retention test task, showed a significant main effect of Training, $F(1,76) = 9.63$, $MSE = 5.12$, $p < .01$, Cohen's $d = 0.70$, indicating that participants who had studied examples invested less mental effort in solving the retention test problem ($M = 5.22$, $SD = 2.60$) than participants who had practiced ($M = 6.82$, $SD = 1.91$). There was no significant main effect of Embodiment $F(1,76) < 1$, nor an interaction effect, $F(1,76) = 2.58$, $MSE = 5.12$, $p = .113$ and indicated that in the Example conditions, the Embodiment Absent condition tended to invest more effort than the Embodiment Present condition on the retention test task, whereas in the Practice conditions, this was the other way around.

### Transfer Test Task

There were no significant main or interaction effects on performance and invested mental effort on the transfer test task (all $F < 1$).

## Discussion

In line with our first hypothesis, we found a large ($d = 0.87$) beneficial effect of example study on test performance. Moreover, the examples conditions reached this higher test performance with less investment of effort during the learning phase (indicating a more efficient learning process), as well as less investment of effort during the retention test (indicating more efficient learning outcomes; Van Gog & Paas, 2008). This finding is in line with prior studies in other domains that have shown higher learning outcomes with less investment of mental effort during acquisition (e.g., Paas & Van Merriënboer, 1994; Van Gog et al., 2006) as well as during the test (e.g., Paas, 1992; Paas & Van Merriënboer, 1994). This effect was limited to the retention test task, though. There were no effects on transfer, which suggests that students in the Example study conditions remembered the procedure (they performed better on the retention test), but did not really understand it sufficiently to be able to adapt it to a new problem situation with an additional object on each side. It would therefore be interesting to investigate whether including verbal explanations by the model, emphasizing the possible options at each step and indicating why the

eventually chosen step is correct and the others are not, would enhance understanding of the solution procedure and thereby, transfer performance.

Regarding our second hypothesis about effects of Embodiment on test performance, we saw a trend in the expected direction, with participants in the Embodiment Absent conditions performing better than participants in the Embodiment present conditions: practicing or studying examples with animal-like plastic objects led to less steps correctly completed on the retention test than practicing or studying examples with wooden discs. However, this difference failed to reach statistical significance ($p = .129$; $d = 0.30$), possibly due to the relatively low number of participants. Therefore, we will replicate this study with a larger number of participants.

## Second Study

We are currently conducting a replication study with a larger number of participants to achieve more statistical power. This study will also include an additional condition in which we will control for the effect of direction. That is, because the animals were embodied, they were also headed in a direction. The discs did not imply any direction. So assuming we would find a significant effect of Embodiment when we have more statistical power, this additional condition will allow us to answer the question of whether this is really due to anthropomorphism (assigning goals and intentions to objects that have a bodily shape) or simply a consequence of implied direction. If so, that would still be an interesting finding in terms of understanding factors that might affect problem solving and the acquisition of problem-solving skills through example study. The results of this second study are expected to be available well before the conference.

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