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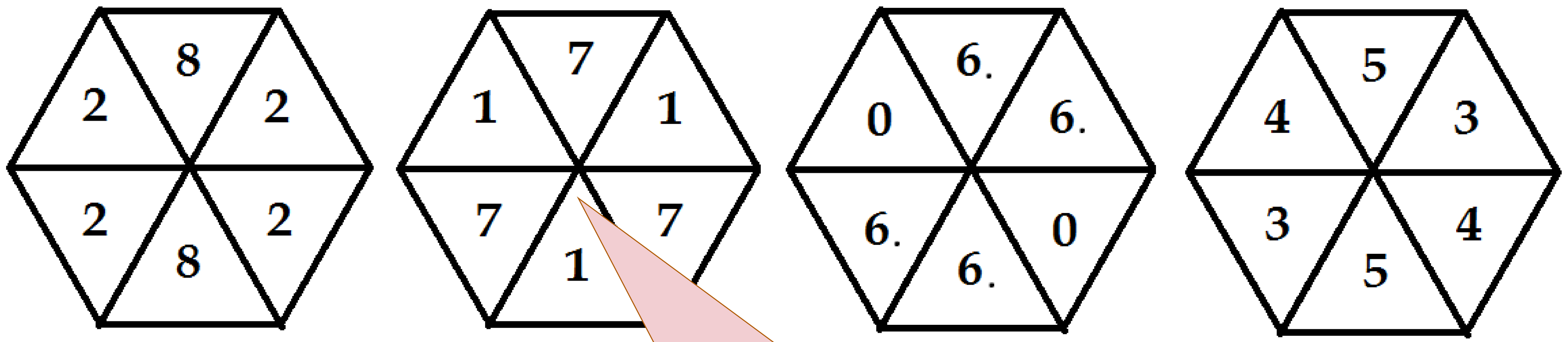


Arranging solution steps & Solving subtasks. Which kind of guidance do learners really need?

Spin the Top!

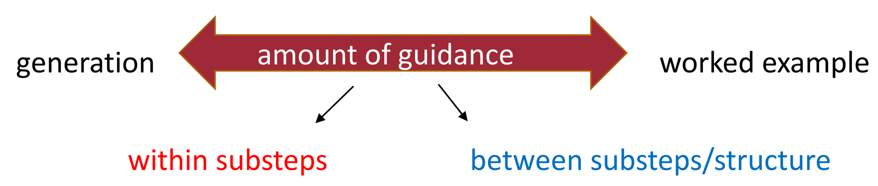
"What would be wiser for you: offering your friend to choose first
or to choose first yourself?
Would it matter at all, given that the sum of all numbers on each top is equal?"

Background

Whereas the didactical conclusion reached from the framework of **desirable difficulties** (Bjork & Bjork, 2011) is to strain the working memory, the didactical advice from **CLT** is the opposite of this: relieving the working memory; not overwhelming a student – as cognitive capacity is highly restricted! Both frameworks have in common that free cognitive resources should be devoted to the learning contents. But they differ in the conclusion how to reach long term learning and transfer.

Particularly the contradiction between the **worked example effect** (Renkl, 2014) and the **generation effect** (Bertsch et al, 2007) is prominent. Chen et al (2015) suggest to resolve this contradiction regarding the complexity as a moderator factor for the application of the generation activity. The worked example effect occurs for materials with high element interactivity, whereas the generation effect occurs in cases of low element interactivity. The current study addresses the questions of the implementation of the generation activity for complex probability tasks regarding the opportunities for cognitive engagement of learners.

In classical investigations the learning performance after studying a worked out example was compared to the learning performance from learning through problem solving. Worked example effect was explained by relieving the working memory with guidance. But it was not considered, that „guidance" can be related to separated aspects of the learning task which are immanent to it. A complex task contains many substeps, therefore guidance can be related 1). to the order of the substeps, which is constantly regular and 2). to the solution of each step separately. So in the current study the learning task varies in the amount of two kinds of guidance. The main question for this investigation is, which kind of guidance is related to the learning success according to the worked example effect and what can learners generate by themselves.



Keywords: generation effect, worked out example, desirable difficulties, problem solving, probability calculation.

Hypotheses

I: Both kinds of generation – solving of subtasks and arranging the order – encourage different cognitive processes and thus have a different impact on a learning performance. Whereas solving might increase the procedural knowledge, the quasi randomized order enhances more conceptual understanding.

II: According to the expertise reversal effect (Kalyuga et al, 2003) low knowledge students might benefit from a maximum of guidance whereas high knowledge students don't need as much support and may gain more from sophisticated learning materials.

III: The generation effect might apparent only if learners successfully generate. The more right solutions they attain in the solving conditions the higher the gain of the generation activity.

IV: Generation as a desirable difficulty might not increase the intrinsic and extraneous load, but rather the germane load.

Learning materials

A complex well structured probability calculation task containing separated subgoals with a similar procedures differed in element interactivity: each pair of tops had to be compared.

This is the way to calculate the probability of the top with number 6 winning against the one with 5:

What is the highest value of the „6" top? How often does this number occur?

How high is the probability of getting a 6 on the „6" top?

Calculate the probability as a fraction. Consider the fact that the top has six sides.

Would it be possible for you to beat your friend with the „5" top in case he gets a 6 with the „6" top?

Are there other values on the „6" top which are higher than those on the „5" one?

To calculate the probability of beating the „5" top with the „6" one you have to multiply the probability of getting a 6, by 1 (because 6 would always win). In this certain case this probability is identical to the probability of just getting a 6.

Comparison: „6" top vs. „5" one. From the „solving"- condition.

Sample

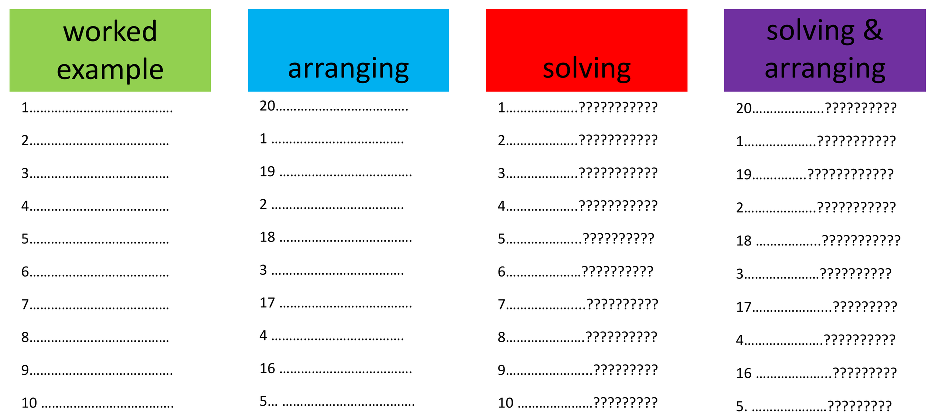
- 107 prospective teacher students from the lesson „Introduction to Educational Psychology": in average 21,4 years old, W=61.7%, 2/3 from the first semester.
- 63 participants were randomly assigned to the four experimental conditions.
- 44 participants in the control condition – students who were absent during the lesson (treatment) but were tested for the learning outcomes.

Design

The design of the task materials varied between the participants in two factors:

1. The amount of guidance in the **arrangement of the solution steps** – the order of solution steps was regular (high) vs. the order of steps was quasi randomized and had to be rearranged (low).
2. The amount of guidance **within the solution steps** – students only had to comprehend the steps (high) vs. to follow instructions in order to actually solve the subtasks (low).

Guidance in arranging the subtasks / Guidance in solving the subtasks	high	low
high	worked example	arranging
low	solving	solving & arranging



Before the learning phase the participants were examined in their previous knowledge of probability calculation. Immediately after the learning phase participants filled out questionnaires for cognitive load and learning experience.

The effect of desirable difficulties might be visible in a long term rather than in a short term. Thus the examination of the learning performance was one week after the learning phase. Participants from the experimental conditions and the control group were examined in: conceptual understanding, near and far transfer.

Results I

		worked example	arranging	solving	arranging & solving	
Learning Pre-requisites	previous knowledge	9.8 (3.2)	9.4 (2.6)	8.1 (3.2)	7.9 (3.5)	=
Learning activity while studying	time on task min.	12 (5.5)	13.6 (4.5)	17.5 (3.5)	18.4 (5.8)	≠ p=.001
	success of solving	-	-	11.9 (4.8)	6.9 (4.4)	≠ p=.008
	amount of notes	2.5 (3.7)	4.4 (5.9)	-	-	=
Cognitive Load	overall	4.6 (3.1)	4.4 (2.8)	5.1 (2.7)	4.9 (2.6)	=
	intrinsic	4.9 (2.0)	5.0 (2.4)	5.3 (2.0)	5.1 (2.6)	=
	extraneous	4.7 (2.0)	4.7 (2.3)	4.4 (2.1)	4.2 (2.3)	=
	germane	4.6 (2.1)	3.4 (2.8)	4.3 (2.6)	3.5 (2.1)	=
Learning experience	competency	4.1 (3.5)	3.2 (1.7)	3.1 (1.4)	3.1 (1.7)	=
	autonomy	2.9 (1.0)	2.6 (1.0)	2.5 (1.1)	2.4 (1.3)	=
	enjoyment	2.5 (1.0)	2.3 (1.7)	2.3 (1.0)	2.3 (1.6)	=
	intr. motivation	3.2 (0.8)	2.9 (1.1)	3.0 (0.9)	2.8 (1.5)	=
	comprehension	2.2 (1.1)	1.6 (0.8)	3.1 (1.6)	1.5 (0.9)	≠ p=.001
	performance expectancy	3.0 (1.5)	3.0 (1.9)	3.0 (1.2)	2.7 (2.1)	=
Learning performance	conceptual understanding	13.7 (2.8)	14.1 (2.6)	14.1 (1.7)	13.3 (3.2)	=
	near transfer	1.0 (0.7)	0.9 (0.7)	1.0 (1.0)	0.8 (0.7)	=
	far transfer	4.0 (2.7)	4.1 (3.2)	4.7 (3.0)	3.6 (3.1)	=

	success of solving	amount of notes
Conceptual understanding	.390 m.s.	-.401*
Near transfer	.512*	-.022
Far transfer	.593**	-.128

	germane load
Success of solving	.157
Amount of notes	-.090
Conceptual understanding	.053
Near transfer	.000
Far transfer	.039

Correlation between cognitive engagement and learning performance – under control of previous knowledge and time on task.

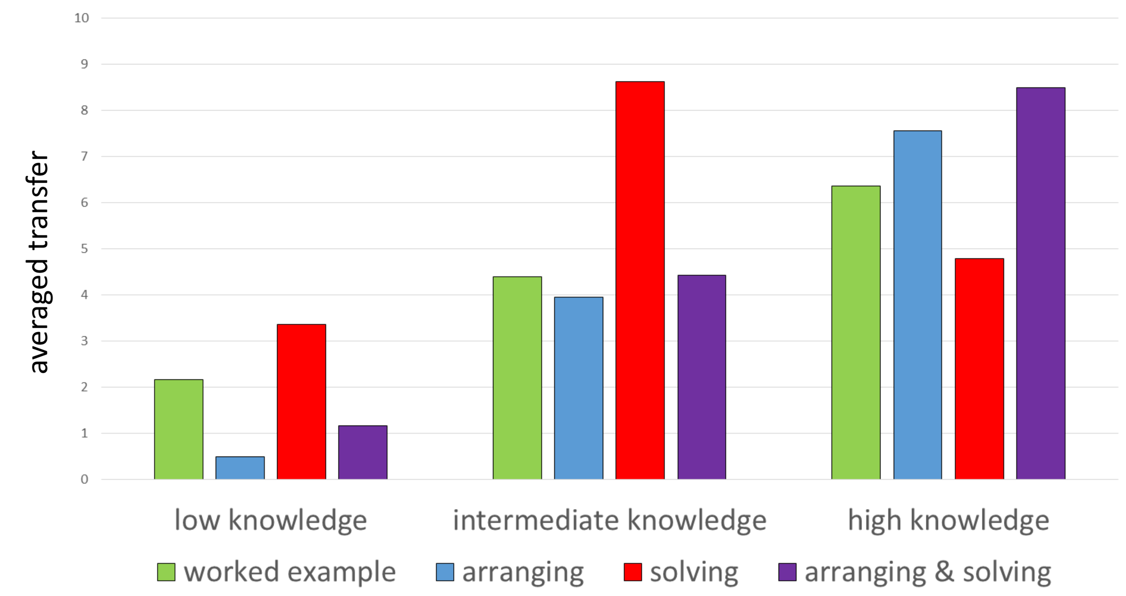
Results II

Experimental conditions vs. Control condition:

Conceptual understanding: M=13.78 (SD=2.59) vs. M=13.10 (SD=2.52), t(99)=1.323, p=.189.
Near transfer: M=0.95 (SD=0.77) vs. M=0.66 (SD=0.77), t(105)=1.931, p=.056.
Far transfer: M=4.10 (SD=2.93) vs. M=3.03 (SD=2.67), t(105)=1.933, p=.056.

Arranging * Solving * Previous knowledge:

Conceptual understanding: Previous knowledge F(2,47)=7.053, p=.002, Eta=.231.
Near transfer: Previous knowledge F(2,51)=10.625, p<.001, Eta=.294.
Prev. Knowledge*Arranging F(2,51)=3.715, p=.031, Eta=.127.
Prev. Knowledige*Solving F(2,51)=2.422, p=.099, Eta=.087.
Far transfer: Previous knowledge F(2,51)=11.008, p<.001, Eta=.302.
Prev. Knowledge*Arranging F(2,51)=3.602, p=.034, Eta=.124.



Discussion

I: There was no different impact on learning performance according to the kind of cognitive activity required by the type of generation task. No effects on conceptual understanding were found. The reason could be that an explicit requirement for ordering the substeps was missing in the instruction. The superiority of the solving condition in transfer was not significant.

II: The expertise reversal effect could be partly confirmed. High knowledge learners benefited from arranging only condition and the condition with combined difficulties; whereas the lower the knowledge of learners the less the learning performance in contrast to the conditions with a regular order of substeps. The challenge of arranging the substeps while presenting the learning materials in a quasi randomized order might be more sophisticated than solving the subtasks. Particularly the challenge of solving turned out to support low knowledge learners: low knowledge students benefit from less guidance within the substeps.

III: The superiority of successful generation could be confirmed for conceptual understanding as well as for transfer. This finding remains even under control of time on task and previous knowledge. Thus the implication for applying generation activity while studying learning materials is to support the students solving the tasks. Guidance does not necessary mean relieving of working memory but supporting of self regulated activity. In contrast to the quality of generation there were no benefits for quantity of generation activity in comprehending only conditions. The spontaneous self explanations were not beneficial for learning process. Thus students should be engaged in generative activity rather than spontaneous self-explanations and be supported in this activity.

IV: The generation activity didn't increase the intrinsic and extraneous load, but also didn't increase germane load, rather decreased it in arranging conditions (n.s.). This would be compatible with CLT, but at the same time there is no inferiority for the unusual order of substeps in terms of learning performance and also no correlation between mental effort and learning success.

Open questions

The generation activity could be shown in complex tasks – how could it be integrated, described and explained in terms of CLT?

Can it be apriori decided which kind of load certain difficulties induce: intrinsic, extraneous or germane?

Further research and theoretical analysis should aim to resolve the contradictions and overlap in the frameworks of CLT and desirable difficulties.

Literature

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