Effects of the Prior Knowledge and Scaffolding in Facilitating Complex Skills Through Simulations: A Meta-Analysis

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Abstract: Simulation-based learning offers a wide range of opportunities to practice complex skills in higher education. This meta-analysis investigates the effectiveness of different scaffolding types to foster complex skills through simulations by analyzing 145 empirical studies with total sample of 10532 participants. We conclude that simulations provide effective means to facilitate learning of complex skills and different scaffolding types can effectively facilitate learning in different phases of skill development.

Extended summary

Theoretical background and method

The meta-analysis grounds on the claims of expertise development theories (e.g., Van Lehn, 1996) and empirical research on problem solving and simulation-based learning, which provides supportive evidence to the effectiveness of learning through problem-solving in postsecondary education (e.g. Belland et al., 2017), and to simulation-based learning in particular (e.g. Cook, 2014).

In addition, evidence from prior meta-analyses (e.g. Gegenfurtner, et al., 2014) states the positive effect of scaffolding on various learning outcomes. However, synthesized results on the role of instructional support in learning complex skills through simulations are lacking, especially concerning effective support for learners with different levels of prior knowledge. Therefore, this meta-analysis uses the framework of distinguishing scaffolding types based on levels of self-regulation required (Chernikova et al., 2019) and aims at generalizing the findings of Chernikova and colleagues (2019) to the broader scope of complex skills.

The research questions comprised the role of simulation-based learning environments in development of complex skills in the context of higher education, added value of scaffolding within simulations, and interaction between scaffolding types and learners prior´ knowledge. To address research questions, state of the art meta-analysis (Borenstein et al, 2009, Tanner-Smith, et al., 2016) was performed on the empirical studies from the domains of medical and teacher education, nursing, psychological counselling and management.

Summary of the results

The simulation-based learning had a large positive effect on fostering complex skills: g = .85, SE = .08, 95% CI [.69; 1.02]. The analysis also identified high heterogeneity between studies, Q (409) = 4213.93, $p < .0001$; τ^2 = 1.2; I^2= 95.86% justifying further moderator analysis. All scaffolding types, except for prompts alone, had positive, but rather small effects on learning beyond the effects of simulation itself (see Table 1). The effectiveness of the scaffolding also interacted significantly with learners´ prior knowledge (see Figure 1). Learners with a high level of education benefited more from simulations with reflection phases included; learners with low prior knowledge from scaffolding that provided more guidance (i.e., examples).

Table 1: Effects of the scaffolding on learning complex skills

Scaffolding	Effect size (g)	95% CI	N of studies	Heterogeneity (I^2)
No scaffolding	0.76	[.19; 1.32]	19	92.66%
Examples only	0.66	[.22; 1.10]	27	93.04%
Prompts only	0.44 ns	[-.18; 1.07]	11	90.94%
Reflection phases only	0.81	[.57; 1.06]	15	65.56%
Examples + Prompts	1.60	[.87; 2.34]	4	30.85%
Examples + Reflection	0.95	[.36; 1.54]	15	97.98%
Prompts + Reflection	0.10 ns	[-.27; 0.48]	8	73.53%

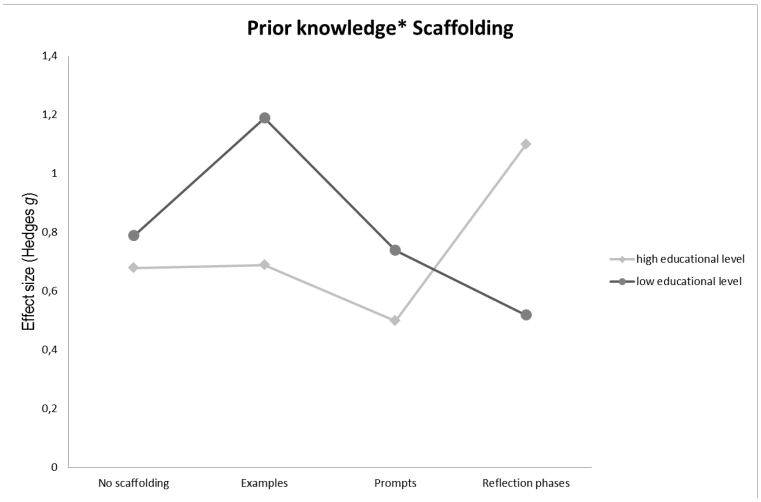

Figure 1. Differential effectiveness of different types of scaffolding for different education levels.

Discussion

This meta-analysis provides further supportive evidence for simulations as effective instructional components in facilitating complex skills (e.g. Cook, 2014). Moreover, it contributes to research on the effectiveness of instructional methods and aligns with findings of a recent meta-analysis (Chernikova et al., 2019), supporting the hypothesis, that learners' prior knowledge defines the scaffolding type that would be effective to foster complex skills. The results further support the claim, that scaffolding should not be removed at the later stages of learning (e.g. Kalyuga et al., 2003), but rather different scaffolding types should be chosen according to the stage of skill development.

The limitations of the current study include (1) rather broad categorization of scaffolding types and (2) very brief descriptions of method in primary studies, which in turn hindered some of the planned analyses.

In conclusion, simulations are effective instructional means and they seem to work across domains and for learners with different levels of prior knowledge. There seem to be types of scaffolding better fitting for earlier and for later phases of skill development. There is an urgent need for more systematic investigations on optimal transitions of different types of scaffolding with increasing levels of complex skills.

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