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Simulation-Based Learning in Higher Education: A Meta-Analysis on Adapting Instructional Support

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Abstract: This meta-analysis includes 143 empirical studies and investigates the effectiveness of different strategies to adapt and individualize instructional support to learners' prior knowledge and performance within simulation-based learning environments. The review identified strategies effective for learners with lower and higher prior knowledge and contributes to the discussion about effective design of learning with simulations. We conclude that (1) adapted instructional support enhances effects of simulations; (2) different strategies of adapting are effective for learners with different levels of prior knowledge.

Problem statement

Empirical research provides supportive evidence on the effectiveness of learning with simulations in different domains of higher education (e.g. Chernikova et al., 2020, Theelen et al., 2019). However, the research also shows that there is no single solution for effective instructional support which would fit all the learners. This paper contributes to deeper theoretical understanding of instructional support and learning, and provides valuable insights for practitioners and policy makers.

Theoretical background and research questions

The current meta-analysis aims at identifying the added value of adaption strategies for learners with low and high prior professional knowledge. This paper is grounded in skill development theories (e.g. Van Lehn, 1996) and empirical research on scaffolding and other instructional support measures, which were found to be beneficial in early stages of skill development, when learners are exposed to complex problems (e.g. Hmelo-Silver et al, 2006).

To capture adaptivity of learning environments we rely on the framework suggested by Plass & Pawar (2020). Under strategy of adapting we understand decisions made by educators, which were implemented and described in the primary studies.

The following research questions were addressed in the paper. (RQ1) In what ways strategies of adaptation are implemented in simulation-based learning environments in higher education? (RQ2) To what extent can these strategies facilitate learning outcomes in learners with higher and lower levels of prior knowledge within simulation-based learning environments in higher education?

Methods and results

The analysis is based on the collection of primary studies and average effects reported in a meta-analysis by Chernikova et al (2020), and is focusing on the added value of instructional support within simulation-based learning environments. A random-effects model and Hedges g estimation were used (Borenstein et al, 2009).

The average effect of simulations on learning was found to be g=.85, SE =.08 (Chernikova et al., 2020). This effect was used as a reference point to estimate the effectiveness of each adapting strategy.

The following adapting strategies (RQ1) were identified in the studies implementing simulations in higher education: (1) fixed adaptation based on the pre-test, (2) adaptation based on performance during simulation, (3) giving participants control over amount of support. The amount of studies implementing these strategies is reported in Table 1.

In regard to RQ2 we were able to identify one strategy, which was beneficial for all learners, a strategy that had some positive tendency for learners with a high level of prior knowledge, but was rather disadvantageous for students with low levels, and a strategy that had positive effects for learners with low prior knowledge and tended to limit learning gain for learners with high prior knowledge. Number of primary studies, effects sizes and standard errors are presented in Table 1.

Discussion

The findings of the current meta-analysis reveal that in simulation-based learning environments learners benefit from the opportunity to decide on the amount and timing of instructional support they get – this stands in some contrast to effects reported a range of more traditional learning environments (cf. Belland et al., 2017). Our findings suggest that within simulation-based learning environments different strategies of adapting are effective for learners with different levels of prior knowledge.

The limitations of this study include (1) a relatively coarse-grained categorization of strategies to adapt instructional support which might be confounded with some implicit instructional support within the simulation-based learning environments; (2) very scarce the description of learning environment in primary studies and (3) focus on only objective measures of learning outcomes.

In conclusion, as hypothesized, the effects of simulations can be enhanced by instructional support measures and adapting the instruction to match learning needs leads to higher learning gains. More research is needed directly comparing different adapting strategies for instructional support to fully exploit the power of simulations in developing complex skills.

Table 1: Effectiveness of adapting strategies

Strategy		**Low prior knowledge**	**High prior knowledge**
Fixed adaptation (based on pre-test)		*N*, Hedges *g*, (*SE*)	*N*, Hedges *g*, (*SE*)
Treatment	used	*N* =1, na	*N* =0, na
	not used	*N*= 56, .81 (.13)	*N*= 59, 1.08 (.11)
Assignment to groups	used	*N* =1, na	*N* =0, na
	not used	*N*= 32, .94 (.20)	*N*= 59, 1.08 (.11)
Instructional support	used	*N* =0, na	*N* =0, na
	not used	*N*= 57, .77 (.13)	*N*= 61, 1.08 (.11)
Performance-based adaptation			
Individualized scaffolding	used	*N* =0, na	*N* =0, na
	not used	*N*= 53, .74 (.13)	*N*= 55, 1.11 (.13)
Opportunity to adjust behavior during simulation	used	*N*= 12, .94 (.21)	*N*= 18, 0.92 (.20)
	not used	*N*= 39, .72 (.16)	*N*= 38, 1.10 (.14)
Change of complexity during simulation	used	*N*= 5, .77 (.23)	*N*= 6, 1.02 (.22)
	not used	*N*= 49, .75 (.14)	*N*= 50, 1.09 (.10)
Fading of instructional support	used	*N* =0, na	*N*= 3, 0.76 (.34)
	not used	*N*= 53, 0.76 (.13)	*N*= 54, 1.09 (.11)
Decision-making authority			
Amount of support	learner	*N*= 11, .88 (.23)	*N*= 16, 1.33 (.30)
	instructor	*N*= 40, .79 (.16)	*N*= 41, 1.08 (.11)
Assignment to group	learner	*N* =0, na	*N* =1, na
	instructor	*N*= 32, .87 (.21)	*N*= 23, 1.13 (.19)
Task order	learner	*N*= 4, .47 (.14)	*N*= 8, 1.13 (.36)
	instructor	*N*= 46, .82 (.15)	*N*= 42, 1.02 (.10)

Note: *N* - number of primary studies, *SE* - standard error, na - insufficient data for effect size calculation

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