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Angaben zur Veröffentlichung / Publication details:

Bauer, Elisabeth, Nicole Heitzmann, and Frank Fischer. 2022. "Simulation-based learning in higher education and professional training: approximations of practice through representational scaffolding." Studies in Educational Evaluation 75: 101213. https://doi.org/10.1016/j.stueduc.2022.101213.

Simulation-based learning in higher education and professional training: Approximations of practice through representational scaffolding

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A B S T R A C T

In this article, we reviewed the nine studies included in a special issue that addresses the assessment and evaluation of simulation-based learning in higher education and professional training. We discussed the results of each study, integrated them in terms of their individual and collective contributions to evaluating the effectiveness of simulation-based learning, and related the studies' results to the presage, process, and product factors of simulation-based learning. We concluded that research on simulation-based learning can benefit from employing a variety of methodological approaches and venturing beyond its primary focus on cognitive processes and outcomes to analyze the different types of process indicators and learning outcomes. Moreover, we identified a promising direction for future research: the selection and adjustment of representations of practice included in simulations by means of representational scaffolding. By proceeding with increasingly detailed analyses of simulation-based learning, research can further advance our understanding of the relevant learning mechanisms.

1. Simulations in higher education and professional training

Simulation-based learning has been gaining increasing attention from both research and instructional design concerned with learning opportunities for higher education and professional training in various professional domains (Chernikova et al., 2020). This special issue aims to consolidate research on the design, use, and effectiveness of simulation-based learning, presenting nine contributions to the assessment and evaluation of simulation-based learning in vocational education, higher education, and professional training in a broad range of disciplines and professions: medical education, mountain rescue, business informatics, political decision-making, automotive mechatronics, and marine navigation.

In our commentary on this special issue, we aim to discuss the individual and collective accomplishments of the contributions and highlight future research directions. First, we will refer to the introduction of Duchatelet et al. (2022) on the assessment and evaluation of simulation-based learning in higher education and professional training. Proceeding from their perspective on the benefits of an educational evaluation of simulation-based learning, we will summarize and discuss the nine papers and highlight their individual contributions regarding what, why, and how participants learn in simulations in the contexts of higher education and professional training. Finally, we discuss the overarching trends in researching educational simulations and suggest directions for future research.

2. Educational evaluation of simulation-based learning

In their introduction to this special issue, Duchatelet et al. (2022) discuss the difference between two perspectives—educational assessment and educational evaluation—on the effectiveness of simulation-based learning in higher education and professional training. They highlight that the assessment perspective mostly focuses on learning outcomes—that is, the *product* of simulation-based learning (see Mislevy, 2013). In contrast, the evaluation perspective aims to consider the underlying mechanisms and processes that make the simulation more or less effective (see Coldwell & Maxwell, 2018; Döring & Bortz, 2016). To illustrate the factors that might need to be considered

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in a comprehensive perspective to evaluate the effectiveness of simulations, Duchatelet et al. (2022) refer to the 3P-model introduced by Biggs (1993; adapted by Tynjälä, 2013) and tailor it to the context of simulation-based learning (see Fig. 1; for a similar model, see also Heitzmann et al., 2019).

The 3P-model relates to the idea of educational evaluation going beyond assessing only the *product* (i.e., outcome) of learning and, in addition, considers the learning *process* and *presage* (i.e., input) factors. In both educational assessment and educational evaluation, the *product factors* refer to the learners' achievements concerning predefined learning outcomes. To more comprehensively evaluate simulations, it is important to also consider the *process factors*—that is, *how* learners achieve certain learning outcomes. The process factors involve learning activities and the question of whether some activities during simulation-based learning are more effective than others. Moreover, the process factors comprise the cognitive, metacognitive, affective, and regulative processes that happen within the individual learners and—if applicable—groups of learners during simulation-based learning. Regarding the interactive and collaborative processes in a group of learners, aspects of communication and other social processes are also relevant. To explain both learning products and processes, research must consider the *presage factors* and their interplay in the context of evaluating the effectiveness of simulation-based learning. These factors can be distinguished in terms of individual presage factors and contextual presage factors. The *individual presage factors* describe a learner's cognitive, metacognitive, affective, and regulative learning prerequisites, such as their prior knowledge and skills. The *contextual presage factors* comprise aspects of the design and implementation of the simulation, ranging from setting learning goals, defining learning tasks, creating stimulus material, and implementing measures to support and guide the learning, such as scaffolding the learning process (e.g., using reflection prompts) or offering debriefing and other types of feedback.

By adopting the more comprehensive perspective of educational evaluation, research on the effectiveness of simulation-based learning can offer valuable insights into the interplay between learner characteristics, characteristics of the simulation context and simulation design, learning processes, and learning outcomes. Such comprehensiveness might offer great value for advancing the design and implementation of simulations, especially for contexts that demand learning complex skills, such as higher education and professional training. We thus draw on the idea of Duchatelet et al. (2022) to link the studies presented in this issue to the 3P-model.

3. Contributions to this special issue

The nine contributions encompass five quantitative, one qualitative, one methodological, and two review studies. The studies stem from different disciplines and professions: political decision-making, mountain rescue, medical education, business informatics, automotive mechatronics, and marine navigation.

Hanus et al. (2022), in the context of professional training, assessed voluntary mountain rescuers' technical and non-technical skills during simulated cardiopulmonary resuscitations (CPR). They investigated how technical skills, non-technical skills, experience, experienced patient deaths, and monitoring skills (i.e., individual presage factors) influence the voluntary mountain rescuers' resuscitation performance (i.e., product factors). To assess the participants' skills and experience, this quantitative multimethod study employed an observation form, questionnaires, and a simulation manikin. The rescuers' technical skills of resuscitation performance were explained by their prior experience of real resuscitations but not simulated resuscitations. In the study sample, unlike some prior studies from the field of medical education suggested, the technical skills and non-technical skills did not correlate significantly. The authors concluded that the relationship between the skills and experience of the voluntary medical personnel differed from previous research that focused on professional medical staff. The study results highlight that learner characteristics, such as the level of prior training, can vary significantly—not only across individual and groups of learners but also across (sub-)disciplines. When using simulations for learning or assessment, it is thus relevant to be aware of the target group's learner characteristics (i.e., individual presage factors).

Vermeiren et al. (2022) assessed students' self-efficacy for negotiating during a four-day role-play simulation of political decision-making. In this quantitative longitudinal survey study with multiple measurement points across the simulation, the authors investigated how variations in higher education students' self-efficacy for negotiating (i.e., product factors) were explained by gender and experience (i.e., individual presage factors), as well as negotiation opportunities and the preparation for the simulation process (i.e., contextual presage factors). The variables of gender, simulation experience, and opportunities to practice negotiation during the simulation appeared to explain the variations in students' self-efficacy. However, contrary to prior research, this study did not find a significant increase in students' self-efficacy for negotiation over time. The authors explained this finding in terms of the simulation features of their multi-agent role-play simulation (i.e., contextual presage factors), in which the majority of participants indicated that they lacked opportunities to practice their negotiation skills sufficiently and, thus, did not experience successful negotiations. As demonstrated by this study, besides considering learner characteristics, carefully designing the learning task and opportunities to practice the task are also essential to achieve the expected learning outcomes with simulations.

Duchatelet & Donche (2022) derived methodological opportunities and challenges from applying a longitudinal case study design (i.e., process factors) to a role-play simulation of political decision-making (see Vermeiren et al., 2022). Longitudinal case study designs are advantageous in that they can emphasize learning processes in specific contexts while considering multiple sources of evidence. This study focused on learners' (a) negotiating performance and (b) self-efficacy for negotiating. The sample included four students who adopted different roles in the simulation. Six different data sources were used: a diary, repeated interviews during the simulation, observations and field notes, pre- and post-simulation interviews, reflection reports, and an assessment form. The longitudinal case study design was found to be a

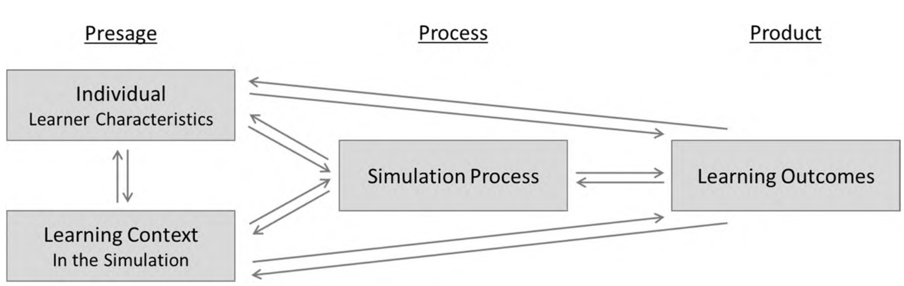

Fig. 1. The 3P-model of simulation-based learning
(adapted from Biggs, 1993; Duchatelet et al., 2022; Tynjälä, 2013).

valuable research strategy for gaining insights into students' learning during simulations. Such a design, the authors argued, yielded insights into the interplay of the explanatory variables for developing self-efficacy, which are reported in a separate article (see Duchatelet et al., 2020). However, they also identified challenges, such as choosing a suitable sample or finding the right timing for the multiple assessments.

Hühn & Rausch (2022) analyzed collaborative learning and emotions in a three-day digital simulation game concerned with general management in higher education courses in business informatics. In this quantitative evaluation study, six groups of four to six students learned with the simulation, which was divided into six periods of play. After completing the questionnaires on several individual dispositions (e.g., personality traits; i.e., individual presage factors), the students were asked repeatedly to indicate their subjective evaluation of the collaboration and emotional experience during each break between the six periods of the simulation (i.e., process factors). The researchers then assessed the in-game performance (i.e., process factors) and knowledge outcomes (i.e., product factors). The study did not provide support for a strong connection between the learners' personalities and the assessed process and product indicators. However, the results suggest that a positive subjective evaluation of the collaboration and emotional experience is related to higher in-game performance and self-assessed knowledge outcomes. The authors concluded that there is a need to organize and structure collaborative processes in simulations carefully to support performance and knowledge acquisition.

Sellberg et al. (2022) analyzed a simulation-based competence test in a maritime navigation course in a higher education master mariners program. First, the learners demonstrated their navigational competences in a simulation-based competence test, in which they acted as navigators in a navigation simulator. After, they were invited to share their reasoning in an accountable talk, in which the teachers and students discussed the previous performance (i.e., process factors). This qualitative study, which first used an ethnographic fieldwork approach and then a videography approach, analyzed the activities of learners in the simulation and in the accountable talk. It was found that, through the accountable talk, simulations can contribute to students' professional confidence and professional identity. The authors conclude that focusing on accountable dialogue offers the potential to further exploit the benefits of simulations as assessment and learning environments. In such dialogues, teachers rely on assessment criteria while still supporting students' learning and professional identity (i.e., product factors).

Soellner et al. (2022) analyzed the effects of first-person-view videos as a feedback method (i.e., contextual presage factor) on the CPR performance and team performance (i.e., product factor) in a resuscitation simulation in medical education. In this quantitative experimental study, final-year medical students in teams of four participated in a scenario-based simulation that used simulation manikins. Their performance was recorded using head-mounted cameras. In the experimental group, the students watched a video in first-person-view immediately before the debriefing session. The control group had a longer instructor-led debriefing session. Both groups were found to improve their CPR performance and their team performance from pre- to post-test. However, when comparing the groups, no significant difference in the CPR performance score was found. The authors concluded that including first-person-view videos is feasible in simulation-based courses in medical education. However, compared to a longer debriefing session, there seemed to be no direct benefit for the learning outcomes. This was possibly because the longer debriefing session itself had positive effects as well. To fully use the potential of first-person-view videos, their instructional embeddedness thus seems crucial.

Meier et al. (2022) developed and evaluated a simulation-based learning environment with modeling examples (i.e., contextual presage factor) for the vocational education of automotive mechatronic technicians. In the digital simulation, the apprentices received modeling examples concerned with complex car malfunctions. An expert survey reviewed the instructional materials. Then, after slight adaptations suggested by a pilot study, an evaluation study was conducted. The participants received an instructional video and modeling examples. It was found that the simulation promoted diagnostic knowledge and scaffolded diagnostic skills. The perceived extraneous load was relatively low. However, the participants were found to be unable to transfer their knowledge to another diagnosis in the simulation (i.e., product factor). The authors concluded that the learners were still overwhelmed by the task of diagnosing complex car malfunctions and would have benefited from further scaffolding. Moreover, both interest in the diagnosis but also perceptions of the diagnosis as being challenging decreased. The authors highlighted a substantial variation in the motivational factors in the sample, which must be investigated in further studies, and offered ideas for slight modifications that might further increase the effectiveness of the learning environment, such as providing further scaffolding.

Braunstein et al. (2022) developed a five-level taxonomy on social embedding in learning environments (i.e., contextual presage factor): 1) social placement, 2) social action, 3) social reaction, 4) social interaction, and 5) collaborative interaction. The authors conducted a systematic review, categorizing virtual learning simulations—an exclusively digital format in which reality is replicated as closely as possible—in vocational and professional learning according to the taxonomy. In the systematic literature review, 23 studies were identified. The sample encompassed studies from different fields, such as economics or healthcare. In five simulations, a fictitious person approached the learners with a task (i.e., social action). In nine simulations, the learners had to approach others (i.e., social reaction). In five simulations, the learners had the opportunity to ask for feedback or request help (i.e., social interaction). In four simulations, the learners collaborated to solve the given task (i.e., collaborative interaction). The authors concluded that the taxonomy can be used for analyzing and designing learning tasks as well as the technical environment of virtual learning simulations. Most simulations were identified in the review as having a relatively high level of social embedding. In addition, the authors generally recommend increasing the level of social embedding to further increase the immersive dimension of virtual learning simulations.

Hofmann et al. (2021) analyzed three key non-technical skills—teamwork, communication, and decision-making—in simulation-based learning in medical education. Using a scoping review, the study addressed the current lack of robust outcome measures in this field (i.e., product factors). Using a qualitative content analysis of the UK medical education and postgraduate curricula, the study identified consistent definitions and operationalization of learning objectives related to non-technical skills in medical education (i.e., contextual presage factors). By integrating the scoping review and the qualitative content analysis into a comparative analysis, the study identified validated assessment instruments and compared the currently used instruments against learning objectives in the medical education curricula. The scoping review analyzed a final set of 72 studies and found 27 instruments related to non-technical skills, of which 14 were validated and publicly accessible. Within the content analysis, 21 key learning objectives were identified and used as conceptual dimensions for analyzing the link between the currently used instruments and the learning objectives. As the comparative analysis revealed, many of the already-used outcome measures address the curricular learning objectives. However, not all objectives were found to be covered by the outcome measures (e.g., the use of evidence-based reasoning). This study shows that there is no consistent use of instruments for assessing non-technical skills in simulations in medical education. The currently used instruments, the authors suggest, lack a strong conceptual and methodological framework, and such a framework must be established for developing effective simulations for facilitating non-technical skills in medical education and potentially also in other fields.

4. From a status quo to a quo vadis in researching simulations for professional education

The studies included in this special issue describe a set of different methods for assessing and evaluating simulation-based learning. Overall, they exhibit a tendency to make use of multiple data types and data sources as well as multimethod or longitudinal approaches. This might illustrate a trend of venturing beyond investigating the effectiveness of simulation-based learning for achieving certain learning outcomes compared to other interventions (i.e., product factor), which is already supported by robust evidence consolidated by meta-analyses (e.g., Chernikova et al., 2020; Cook, 2014; Hegland, 2017). Instead, research increasingly seems to focus on improving the understanding of the learning processes in simulations as well as on investigating the potential interactions between the presage, process, and product factors. As highlighted by Hofmann et al. (2021), research is yet to generate a sufficient evidence base to fully understand which features of the simulations maximize the effects and for which learners, which learning objectives, and under which conditions these features do so. It thus seems valuable to collect and analyze rich data from various data sources (e.g., Hanus et al., 2022; Hühn & Rausch, 2022) and—especially to investigate learners' processing of simulations—various measurement points (e.g., Duchatelet & Donche, 2022; Hühn & Rausch, 2022; Vermeiren et al., 2022). Moreover, the use of qualitative and ethnographic methods seems to be gaining popularity as well, because they can offer detailed insights into the processes and outcomes captured by verbal or video data (e.g., Sellberg et al., 2022). However, at least in the studies included in this special issue, simulation-based learning was primarily investigated using quantitative methods and analyses. To further improve the understanding of why, how, and under which conditions simulations offer optimal learning benefits, future research on simulation-based learning could consider employing diverse methodological and analytical approaches.

The majority of the studies in this issue focused on cognitive processes and outcomes of simulation-based learning. However, some of them also considered the affective and social aspects of learning (e.g., Braunstein et al., 2022; Hühn & Rausch, 2022 Vermeiren et al., 2022). Focusing on cognitive outcomes is legitimized by the central learning goal of professional education: to facilitate professional knowledge and skills. However, regulative (e.g., self-regulation, self-reflection) and affective outcomes (e.g., self-efficacy, motivation, interest) are also relevant to professional learning (Duchatelet et al., 2022; Pintrich, 1994). Compared to many cognitive outcomes, such as domain-specific knowledge and skills, regulative outcomes may indicate the learning of more generalizable skills, which are, nevertheless, important for coping with the full complexity of professional practices (e.g., Brydges & Butler, 2012; Virtanen et al., 2017). In addition, various affective outcomes can be considered indicative of the development of a professional attitude, which is an integral part of professional competence (see Mulder et al., 2009). Also Sellberg et al. (2022) highlighted the relevance of developing not only professional skills but also professional confidence and a professional identity in the course of professional education. Aside from their individual relevance, regulative and affective outcomes can facilitate learners' situational performance and the transfer of learned knowledge and skills. For example, as Vermeiren et al. (2022) highlighted, self-efficacy is considered to exert positive effects on learners' academic achievement (Bandura, 1997; Richardson et al., 2012). In light of this, in addition to cognitive outcomes, further research on the effects of simulation-based learning could consider assessing regulative and affective outcomes more systematically.

Similarly, to comprehensively understand what makes simulation-based learning effective, the assessments of the learning processes in simulations might benefit from considering a variety of not only cognitive but also affective, metacognitive, regulative, and possibly social processes more often. For example, Hühn & Rausch (2022) found that having positive emotions and a positive perception of collaboration with other learners is related to higher performance during the simulation and to higher self-assessed knowledge scores in the post-test. As highlighted by Braunstein et al. (2022), especially social processes in simulation-based learning seem underrepresented in current research. However, since many professional practices involve a social dimension—such as physicians' interactions with patients, teachers' interactions with students, or collaborations between coworkers of any profession (see Fischer et al., in press)—social processes are a highly relevant aspect of learning to perform these professional skills. In addition, considering, for example, vocational education at the workplace or the internships of higher education students, professional learning in real professional settings involves social interactions with trainers or more advanced professionals—who offer explanations, modeling, and feedback—as well as social interactions with peer learners. Therefore, future research and instruction involving simulations in professional education could implement and evaluate the processes of social interaction and collaboration more systematically (see Braunstein et al., 2022).

Furthermore, the studies in this special issue illustrate a variety of simulation types for employing simulation-based learning in higher education and professional training, ranging from role-play simulations—partially in combination with simulation manikins—to digital simulations. Despite the diverse types of simulations presented in the special issue, they generally seem to attempt to achieve high degrees of authenticity. This is in accordance with a general emphasis on the role of authenticity in research on simulation-based learning in professional education (e.g., Chernikova et al., 2020; Codreanu et al., 2020). Moreover, as evidence from a meta-analysis suggests, simulations with an overall high authenticity rating are, indeed, associated with larger effect sizes than simulations with a lower authenticity rating; however, simulations with low authenticity ratings still have large effects that exceed the effects of many other forms of instruction (Chernikova et al., 2020). In addition, as some studies suggest, higher degrees of authenticity do not necessarily make a difference in terms of the simulations' effectiveness concerning learning and the transfer of complex skills (e.g., Gulikers et al., 2005; Norman et al., 2012). This pattern of findings might be explained by the different approaches taken to define authenticity as well as the variations in the aspects of the simulation that are characterized as authentic. Several literature reviews in medical education suggest distinguishing between two types of authenticity: *physical authenticity* refers to whether the simulation looks realistic, whereas *functional authenticity* refers to whether the simulation addresses the critical elements that demand relevant behaviors to complete the learning task (Hamstra et al., 2014; Maran & Glavin, 2003; Norman et al., 2012; see also Choi et al., 2014). With regard to achieving cognitive learning outcomes, the functional authenticity of the simulated learning task seems to be the decisive type of authenticity (Norman et al., 2012), as it focuses on the aspects of the learning task that are relevant to learning a certain skill and therefore must be practiced. In contrast, some studies suggest that affective outcomes, such as motivation or interest, might be influenced by the physical authenticity of the simulation-based learning environment (e.g., Yang & Goh, 2022). The descriptions of the simulations presented in this issue's contributions seem to focus primarily on the aspects of physical authenticity and less on describing the extent to which the simulations are functionally equivalent or how they differ from authentic representations of professional practices. In addition, Hofmann et al. (2021) noted that many studies on simulation-based learning do not offer sufficiently detailed descriptions of the simulations and additional interventions (see also Gross et al., 2019). This underrepresentation of the simulations' functional characteristics might be explained by a generally insufficient theoretical basis for conceptualizing the characteristics of the learning task in simulations designed for learning professional practices—that is, the task of learning to engage in professional practices.

Having a conceptual basis for characterizing the professional practices that are to be simulated in sufficient detail seems vital for exploiting the potential that simulations offer in professional education. On the one hand, such a conceptual basis might facilitate the use of simulations as a valid assessment and testing tool to derive meaningful conclusions about the learners from any generated evidence (Duchatelet et al., 2022; Stadler et al., 2021). On the other hand, a conceptual basis for characterizing simulated professional practices is relevant for designing and implementing simulations for learning purposes and ensuring that the simulation design is aligned with the targeted learning goals (see Hofmann et al., 2021). Future research could investigate the design and implementation of the learning task in a simulation as a separate contextual presage factor in simulation-based learning, one that is distinct from the measures of instructional support, such as scaffolding the learning process (e.g., using reflection prompts) or providing debriefing and other types of feedback.

In the following section, we introduce a recently proposed framework capable of advancing this research direction. It is concerned with conceptualizing and adapting representations of practice for designing simulations for professional education. It describes several features that characterize representations of practice and offers an orientation to systematically describe the functional aspects of learning tasks in simulations in professional education. Moreover, it suggests how to adjust the demands of a learning task through representational scaffolding, a measure of instructional support implemented directly in the learning task.

5. Representations of practice for conceptualizing and adapting the learning task in simulations

In higher education and professional training, simulations are often designed to help learners learn how to engage in professional practices (Fischer et al., in press). To do so, learners gradually need to master transferring their relevant knowledge and skills to various practice situations. Simulations can thus also be described as approximations of practice (Grossman et al., 2009), where professional practices are decomposed into different representations—that is, different practice situations or case vignettes—that can be recomposed into learning environments (see Fischer et al., in press; Grossman et al., 2009). As a starting point for identifying and researching the functional characteristics of simulated and real-life representations of professional practices, we proposed four sets of *representational features*, informational complexity, typicality, agency, and situation dynamics (see Fischer et al., in press), which are described in further detail below. These representational features facilitate defining the demands associated with engaging in various professional practices. In addition, they allow describing real-life practice situations as well as simulated practice representations. They thus help describing the resemblance or divergence of a simulation compared to the real-life practice that is to be simulated as well as its approximation.

One major instructional benefit of simulation-based learning is that it allows creating varying degrees of the simulation's resemblance or divergence compared to the real-life practices. By adapting the focus and difficulty of the learning task—for example, based on the learners' current level of knowledge and skills (i.e., individual presage factors)—some aspects of the learning task can be highlighted while simplifying others (see Plass & Pawar, 2020). For novice to intermediate learners, such as students in higher education or apprentices in vocational education, until they are able to cope with increasingly difficult tasks, these adaptations usually include a higher degree of support and simplification compared to real-life cases or practice situations (see Van Merriënboer & Sweller, 2010). In contrast, in the context of designing further training for advanced professionals, it might be suitable to create simulations that represent rather realistic approximations of novel or rare practice situations. We suggested characterizing such instances of purposefully selecting and modifying representations of practice to adjust the demands of the learning task in simulations as *representational scaffolding* (Fischer et al., in press). The measures of selecting and adjusting the representations of practice in simulations that specifically target the representational features as leverage points for adjusting the demands of the simulated learning task can be considered *representational scaffolds*. In the following section, we briefly describe the four suggested sets of representational features and offer some examples of the associated representational scaffolds.

The set of representational features addressing *informational complexity* refers to aspects such as the amount and connectivity of information inherent to a practice situation or its representation (Stadler et al., 2019). Informational complexity is relevant to be considered in the simulation design, as high informational complexity (e.g., as in the navigation simulator of Sellberg et al., 2022; or in the automotive mechatronics simulator of Meier et al., 2022) can increase learners' cognitive load, which might limit the learning processes and outcomes while cognitively overwhelming novice learners (see Sweller, 2010). Another relevant aspect of informational complexity is the salience of cues in the total amount of information—that is, the salience of the information relevant for adequately processing a practice situation or representation (Machts et al., 2021; Mamede et al., 2012). *Complexity scaffolds* aim to adjust the informational complexity of representations of practice in simulations, for example, by making relevant information more salient. Highlighting the relevant information would be an option to avoid overwhelming learners, however, without the negative effects (e.g., on motivation) sometimes associated with highly structured approaches to learner support, such as modeling examples. Thus, complexity scaffolds that increase the salience of cues might be promising for the automotive mechatronics technicians simulator introduced by Meier et al. (2022). Similarly, in the navigation simulator presented by Sellberg et al. (2022), such complexity scaffolds might support, in particular, those learners with low levels of relevant learning prerequisites.

A second set of representational features refers to the *typicality* of specific cases or situations in a professional field (Papa, 2016). Typicality can be distinguished in terms of prototypicality, which ranges from prototypical to atypical, and exemplarity, which ranges from frequent to infrequent. A prototypical practice situation or case vignette matches the blueprint of the practice situation as it would be described in a textbook and is, thus, rather easy to process. In comparison, atypical practice situations or case vignettes involve patterns of information that deviate from this prototype and are less likely to be processed adequately, especially by novice learners (see Papa & Elieson, 1993). The second subcategory of typicality is exemplarity, which describes the prevalence of different exemplars of practice situations or cases within a domain. Exemplarity can be considered to range from more to less frequent, thus determining the likelihood that a professional will gain or has already gained experience with a similar exemplar of a concrete case or scenario. *Typicality scaffolds* can be used to purposefully incorporate variations of typicality across practice situations or cases into the simulation design, for example, by selecting representations of practice, which occur rather frequently in everyday practice, as in the simulation by Soellner et al. (2022) and Hanus et al. (2022). For those simulations, it might also be possible to include less frequently occurring or particularly atypical cases to train more advanced learners.

A third set of representational features addresses professionals' *agency* while engaging in professional or simulated practices. The demands concerning professionals' agency associated with a practice situation or representation can be partly determined by identifying the required activities for adequately engaging in the respective practice situation. These might consist, for example, in problem-solving activities (e.g., planning, executing, and monitoring; Liu et al., 2016) or epistemic activities (e.g., identifying problems, generating hypotheses, generating and evaluating evidence, and drawing conclusions; Fischer et al., 2014). In addition to such cognitive activities, many practice situations require social activities (e.g., sharing information, negotiating, regulating collaboration, and maintaining social interaction; Liu et al., 2016; see also Braunstein et al., 2022). A simulation focusing on the social aspects of professional practices (negotiating during political decision-making) is described by Vermeiren et al. (2022). Besides the required activities, practice situations and representations can differ in terms of the required degree of self-regulation—that is, how flexible professionals must be in their actions and thinking (see Moilanen, 2007). The required degree of self-regulation might differ depending on the structuredness and standardization of a given practice situation as well as the number of potential activities to choose from. When designing a simulation, *agency scaffolds* can be applied to adjust the comprehensiveness of the required activities and the required degree of self-regulation of a practice representation compared to a real-life practice situation. Agency scaffolds are already included in the simulation of political decision-making, as there are specific social roles and sets of tasks assigned to the participants (Vermeiren et al., 2022). Another set of agency scaffolds that is not yet considered in that simulation would target the learners' self-regulation—for example, guiding them to better prepare for the simulated situation so that they can benefit more from the simulation. Agency scaffolds might also be promising for the CPR simulation described by Soellner et al. (2022). The simulation could offer some possibility for using first-person-view videos as a resource for preparing and guiding the social activity of debriefing.

A fourth set of representational features refers to the *situation dynamics* that do not result from the professional's intervention but from the changes in the practice situation itself over time (Frensch & Funke, 1995; Stadler et al., 2019). The situation dynamics of different practice situations can vary in terms of their progression, which might be more or less stable and more or less predictable. For example, the progression might approximate linearity, or resemble any nonlinear dynamic, or involve sudden changes after reaching a certain time or threshold. The situation dynamics of the different practice situations can also vary in terms of their tempo, ranging from an extremely slow tempo, at which changes only become apparent over longer periods, to an extremely fast tempo, at which professionals might still need to identify and process various information. The progression and tempo of situation dynamics might be adjusted when designing a simulation by means of *dynamics scaffolds*. For example, the simulation for mountain rescuers (Hanus et al., 2022) could offer a version with reduced tempo for novice learners, in which they can stop and think about the further processing of the task. In addition, the business informatics simulation (Hühn & Rausch, 2022) could offer novice learners opportunities to deliberately pause the simulation to facilitate the groups' planning of their next steps.

Referring to the representational features of informational complexity, typicality, agency, and situation dynamics helps in describing the functional characteristics and demands of engaging in professional practices. We thus suggest that these representational features can be used to define and describe simulated professional practices in future studies on simulations in the context of professional education. Future research might also investigate the role of the learning task's functional characteristics as a contextual presage factor in simulation-based learning, one that is distinct from measures of instructional support.

Among these measures of instructional support is the representational scaffolding approach. Of course, other measures of learner support contribute to facilitating task processing and learning processes in simulation-based learning as well. Among these are debriefing (e.g., Sellberg et al., 2022; Soellner et al., 2022) and other forms of feedback (e.g., Sailer et al., 2022), as well as the more commonly known types of scaffolding directed at the learning process (e.g., modeling examples, Meier et al., 2022; or reflection prompts; Bannert & Mengelkamp, 2013). However, these measures of learner support aim to facilitate the learning of the main task by providing *additional* information as well as suggesting certain actions or strategies. In contrast, representational scaffolding is implemented in the design of the simulation *itself* and adjusts the demands of the main learning task by selecting and modifying practice representations (Fischer et al., in press), which is why it might be considered an essential part of designing and researching instructional support in simulation-based learning.

6. Conclusion

Future research could increasingly shift its focus away from collecting more evidence for the effectiveness of simulation-based learning to investigating the learning mechanisms involved in simulation-based learning. The current special issue illustrates this trend of researching simulations beyond the educational assessment of their effectiveness with regard to learning outcomes as the *product* of simulation-based learning, instead focusing on the educational evaluation of the mechanisms and processes that make simulation-based learning more or less effective. As demonstrated in the contributions of this special issue, such research might benefit from using diverse data sources and methodological approaches, including longitudinal and qualitative analyses, to analyze learners' processing of simulations in further detail. We found a strong focus on cognitive processes and outcomes in the contributions. However, as some of the studies illustrate, analyzing different types of process indicators (i.e., affective, metacognitive, regulative, and social processes) and learning outcomes (i.e., regulative and affective outcomes) seems vital for further improving the understanding of why, how, and under which conditions simulations offer optimal learning benefits. In this regard, another vital aspect in the educational evaluation of simulation-based learning consists in further researching the effects and interactions of different presage factors—that is, individual presage factors (i.e., learners' prerequisites) and contextual presage factors (i.e., the design and implementation of simulations).

In particular, we identified the functional characteristics of the learning tasks in simulations as an additional contextual presage factor of simulation-based learning that is currently underrepresented in research. This must be addressed more systematically in future research. To advance this research direction, we discussed four sets of features of practice representations—informational complexity, typicality, agency, and situation dynamics—that might facilitate defining and describing the functional characteristics and demands of the learning task of engaging in a professional practice. The suggested representational features highlight leverage points for systematically selecting and adjusting the practice representations by employing representational scaffolding as a means of instructional support that is integrated directly into the learning task. The approach of characterizing the demands associated with the different representations of practice in simulations for professional education and the implied instructional support measure of representational scaffolding offer new directions for future research regarding the design of simulations and the educational evaluation of simulation-based learning. Such research might facilitate the systematic design of simulations and, thus, advance (future) professionals' learning in vocational education, higher education, and professional training.

Declaration of Interest

We have no known conflict of interest to disclose.

Acknowledgements

This research was supported by Deutsche Forschungsgemeinschaft, DFG FOR2385.

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