Representational scaffolding in digital simulations – learning professional practices in higher education

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Abstract

Purpose – To advance the learning of professional practices in teacher education and medical education, this conceptual paper aims to introduce the idea of representational scaffolding for digital simulations in higher education.

Design/methodology/approach – This study outlines the ideas of core practices in two important fields of higher education, namely, teacher and medical education. To facilitate future professionals' learning of relevant practices, using digital simulations for the approximation of practice offers multiple options for selecting and adjusting representations of practice situations. Adjusting the demands of the learning task in simulations by selecting and modifying representations of practice to match relevant learner characteristics can be characterized as representational scaffolding. Building on research on problem-solving and scientific reasoning, this article identifies leverage points for employing representational scaffolding.

Findings – The four suggested sets of representational scaffolds that target relevant features of practice situations in simulations are: informational complexity, typicality, required agency and situation dynamics. Representational scaffolds might be implemented in a strategy for approximating practice that involves the media design, sequencing and adaptation of representational scaffolding.

Originality/value – The outlined conceptualization of representational scaffolding can systematize the design and adaptation of digital simulations in higher education and might contribute to the

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*Frank Fischer and Elisabeth Bauer contributed equally to this article.

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advancement of future professionals' learning to further engage in professional practices. This conceptual paper offers a necessary foundation and terminology for approaching related future research.

Keywords Higher education, Teacher education, Medical education, Scaffolding, Simulations, Professional practices, Representational scaffolding, Core practices of teaching, Entrustable professional activities, Approximation of practice, Representations of practice, Decomposition of practice

Paper type Conceptual paper

Learning professional practices in higher education

Professionals in any field conduct their daily activities, tasks and routines based on their professional knowledge, skills and ideals (Blömeke *et al.*, 2015). The activities as well as the inherent knowledge, skills and ideals the professionals apply collectively amount to their professional practices (Gherardi, 2009; Kelly, 2008), which are realized by individual practitioners (Roth and Lee, 2006). Novice learners entering a profession benefit from engaging in professional practices during their education – for example, as part of a higher education program – to learn the knowledge, skills and ideals relevant and necessary to cope with authentic practice situations. To focus professional education on the most relevant professional practices, two important fields of higher education – teacher education and medical education – have attempted to identify sets of core practices that might be addressed in higher education curricula (Grossman, 2021; Ten Cate and Taylor, 2021).

However, offering students opportunities for engaging in authentic practice situations involves several constraints: access to real-life practice situations is restricted by ethical boundaries, as real-life practice situations involve taking over responsibility (e.g. for students and patients), for which especially novice learners might not yet be sufficiently qualified (Ziv *et al.*, 2003). In addition, because task difficulty cannot be adapted to suit the learning goals and the learners' current level of knowledge and skills, real-life practice situations do not necessarily serve as ideal learning opportunities or tasks.

An effective instructional approach that eludes these constraints entails the use of simulation-based learning (Chernikova *et al.*, 2020). Simulations are simplified but valid representations of natural, social or artificial systems, which include features that learners can manipulate (e.g. to approximate practice; Heitzmann *et al.*, 2019; Sauvé *et al.*, 2007). Using simulation-based learning provides learners with opportunities for engaging repeatedly in professional practices without facing or generating real-life risks (Heitzmann *et al.*, 2019). In addition, designing simulations allows instructors to balance the learning tasks' authenticity and difficulty – for example, by simplifying practice situations and incorporating additional learner support to avoid overwhelming novice learners (Codreanu *et al.*, 2020).

Existing literature on designing simulations primarily focuses on process models addressing the steps of designing simulations for specific contexts, for example designing simulation for research purposes (Fink *et al.*, 2021) or designing simulations as teacher practice spaces (Reich *et al.*, 2018). Such frameworks typically outline design steps by referring to specific examples of simulations and often touch on discussing selected characteristics of simulations, such as authenticity. There is, however, a lack of conceptual frameworks theoretically deriving leverage points for balancing the learning tasks' authenticity and difficulty, for example by selecting, adjusting and sequencing representations of practice when designing simulations.

To address this gap, we introduce the idea of representational scaffolding for systematically adjusting the task difficulty of a simulated practice situation. To employ representational scaffolding in simulations, the representations of practice are purposefully selected and adjusted to ensure that the demands of the simulated practice situations align with the learners' current levels of knowledge and skill. As part of our conceptual work, we propose a set of representational scaffolds that target relevant leverage points for selecting and adjusting the representations of practice when designing simulations for the education of teachers and physicians. This set of representational scaffolds might serve as a starting point for advancing research on facilitating professional practices by employing representational scaffolding in simulation-based learning in higher education.

Professional practices in teacher and medical education

Aiming to identify reference points for the teaching and learning of professional practices in higher education, researchers and educators in several higher education fields have attempted to identify their fields' core practices that can be systematically addressed in higher education curricula. Teacher education has increasingly emphasized that learning in higher education must be aligned with relevant professional practice situations (Cochran-Smith and Zeichner, 2005; Grossman and McDonald, 2008; McDonald *et al.*, 2013). In particular, the Core Practice Consortium, a group of teacher educators in the USA, as well as several of its associated groups, such as TeachingWorks at the University of Michigan, engage in the ongoing identification and discussion of the core practices of teaching (CPoT; also referred to as high-leverage practices; Grossman, 2021). According to Grossman (2021, p. 4) CPoT "are identifiable components (fundamental to teaching and grounded in disciplinary goals) that teachers enact to support student learning." To identify the relevant CPoT, Grossman *et al.* (2009b) suggested a set of selection criteria:

(1) The CPoT should be highly frequent in teaching.
(2) They can be enacted in classrooms across curricula or instructional approaches.
(3) They should facilitate teachers' professional learning about students and teaching.
(4) They should retain the integrity and complexity of teaching.
(5) They are based on evidence.
(6) They are effective with regard to student achievement.

Based on these six criteria, the Core Practice Consortium identified 19 CPoT (Table 1) to design curricula that center teacher education around high-leverage teaching practices (Grossman, 2021). Several teacher education programs associated with the Core Practice Consortium have gradually implemented such CPoT-centered curricula throughout the past decade (Matsumoto-Royo and Ramírez-Montoya, 2021).

Independently, the researchers and educators in medical education have developed a framework of entrustable professional activities (EPA) to advance competency-based curricula in medical education (ten Cate, 2005). An EPA is defined as a "unit of professional practice that can be fully entrusted to trainees, once they demonstrated the necessary competence to execute this activity unsupervised" (ten Cate and Taylor, 2021, p. 1107). Because the literature started to suggest an increasing variety of EPAs, the Association of American Medical Colleges defined 13 core EPAs (Table 2), which are expected to be performed under indirect supervision on the first day of medical residency and were implemented in undergraduate training in several medical schools in the USA (Amiel *et al.*, 2021). In addition to the Association of American Medical Colleges, national institutions in

CPoT 1	Leading a group discussion
CPoT 2	Explaining and modeling content, practices and strategies
CPoT 3	Eliciting and interpreting student thinking
CPoT 4	Diagnosing particular common patterns of student thinking and development in a subject-matter domain
CPoT 5	Implementing norms and routines for classroom discourse and work
CPoT 6	Coordinating and adjusting instruction during a lesson
CPoT 7	Specifying and reinforcing productive student behavior
CPoT 8	Implementing organizational routines
CPoT 9	Setting up and managing small group work
CPoT 10	Building respectful relationships with students
CPoT 11	Talking about a student with parents or other caregivers
CPoT 12	Learning about students' cultural, religious, family, intellectual and personal experiences and resources for use in instruction
CPoT 13	Setting long- and short-term learning goals for students
CPoT 14	Designing single lessons and sequences of lessons
CPoT 15	Checking student understanding during and at the conclusion of lessons
CPoT 16	Selecting and designing formal assessments of student learning
CPoT 17	Interpreting the results of student work, including routine assignments, quizzes, tests, projects and standardized assessments
CPoT 18	Providing oral and written feedback to students
CPoT 19	Analyzing instruction for the purpose of improving it

Source: Grossman, 2021

Table 1. Core practices of teaching

Core EPA 1	Gather a history and perform a physical examination
Core EPA 2	Prioritize a differential diagnosis following a clinical encounter
Core EPA 3	Recommend and interpret common diagnostic and screening tests
Core EPA 4	Enter and discuss orders/prescriptions
Core EPA 5	Document a clinical encounter in the patient record
Core EPA 6	Provide an oral presentation of a clinical encounter
Core EPA 7	Form clinical questions and retrieve evidence to advance patient care
Core EPA 8	Give or receive a patient handover to transition care responsibility
Core EPA 9	Collaborate as a member of an interprofessional team
Core EPA 10	Recognize a patient requiring urgent/emergent care and initiate evaluation/management
Core EPA 11	Obtain informed consent for tests and/or procedures
Core EPA 12	Perform general procedures of a physician
Core EPA 13	Identify system failures and contribute to a culture of safety and improvement

Source: Amiel *et al.*, 2021

Table 2. Core entrustable professional activities

other countries have adapted the idea of core EPAs as well. For example, in Germany, EPAs were adapted (Holzhausen *et al.*, 2019; Berberat *et al.*, 2019) and included in the graduate profile of the National Competency-Based Catalogues of Learning Objectives for Undergraduate Medical Education (Medizinischer Fakultätentag, 2021; Hautz *et al.*, 2015).

The CPoT in teacher education and the core EPAs in medical education both represent attempts to identify, systematically describe and classify the core practices of the respective professions. The conceptions illustrate that both teachers and physicians need to engage in complex professional practices under conditions of uncertainty (Grossman *et al.*, 2009a). Besides developing technical skills, such as using a rubric for performance assessments as a teacher or the technical aspects of performing a physical examination as a physician (e.g.

using a stethoscope), teachers and physicians need to also develop adaptive expertise, involving the learning of a variety of thinking and social skills (Crawford, 2007). In particular, future teachers and physicians need to learn professional thinking skills, such as problem-solving and reasoning skills (Shulman, 1998; Heitzmann *et al.*, 2019), as well as communication skills and other social skills to interact (and collaborate) with students, patients and coworkers from the own and other professions (Gartmeier *et al.*, 2015; Grossman *et al.*, 2009a). Compared to technical skills, these areas of skill development are more difficult to assess and probably also more difficult to learn in the context of higher education. The conceptualizations of CPoT in teacher education and core EPAs in medical education are, thus, meant to facilitate the assessment, monitoring, documentation and certification of professional practices. In addition, they serve as an orientation for the teaching and learning of engaging in professional practices in higher education.

Approaches to learning professional practices

To support the learning of knowledge and skills for engaging in complex professional practices, Grossman *et al.* (2009a) defined three concepts for guiding the pedagogies of practice in professional education: representations, decompositions and approximations of practice. Confronting learners with relevant representations of practice, such as written case vignettes or filmed practice situations, can make specific aspects of a practice visible to learners within professional education. Practice representations might vary with respect to their authenticity, comprehensiveness, and other features, and this variance is related to two factors. The first factor is the content of the practice representations (i.e. the concrete cases or scenarios that are represented). The second factor is the medial representation (including text, figures, audio, video, virtual or augmented reality) of the cases or scenarios, which might vary depending on how realistically the practice representations depict real-life professional practices. Practice representations must be purposefully selected and possibly modified for teaching and learning. For this purpose, it is necessary to break down professional practice into its components. Grossman *et al.* (2009a) characterize this process as decomposition and emphasize that decomposing (i.e. breaking down) professional practices may facilitate students' focus on the relevant parts of professional practices in their learning. To develop agency for engaging in professional practices, students need to get involved with approximations of practice – that is, with more or less comprehensive and authentic opportunities to engage in professional practices.

A common approach for letting preservice teachers and medical students approximate practice, are internships in which they can observe and explore professional practices under the guidance of an experienced professional. This legitimate peripheral participation in real-life practice situations is considered essential for learning to cope with increasingly complex professional practices (Lave and Wenger, 2001). However, novice learners can easily be overwhelmed by the necessity of breaking down and understanding complex professional practices. This emphasizes the need to provide novice learners with opportunities to get initially involved with scaffolded or otherwise simplified approximations of practice, offering sufficient levels of learner support (Van Merriënboer and Sweller, 2010) and possibilities for repeated attempts.

One option for doing so is using simulation-based learning. Simulations are simplified but valid representations of natural, social or artificial systems (e.g. practice representations) and include features that learners can manipulate (i.e. to approximate practice; Heitzmann *et al.*, 2019; Sauvé *et al.*, 2007). In the context of learning to engage in professional practices, simulations are simplified yet valid representations of professional practices in which learners take on the role of the professional, their colleagues or their nonprofessional interaction partners. The learners engage in activities assigned to a role that may influence the further course of action and interaction in the simulated professional practice. Examples of such activities include drawing conclusions on the likely causes of a problem, predicting trajectories of a practice situation with and without professional intervention or initiating professional interventions. Simulation-based learning offers a feasible opportunity for learners to engage in representations of professional practices repeatedly without facing or generating real-life risks (Heitzmann *et al.*, 2019). Evidence from meta-analyses supports the assumption that simulation-based learning is an effective approach to facilitate the learning of complex skills in higher education (Chernikova *et al.*, 2020). Especially digital simulations (e.g. virtual patients in medical education) have been gaining increasing popularity in higher education (Gegenfurtner *et al.*, 2014), as they facilitate offering repeated practice in a standardized, risk-free, yet authentic learning environment to large numbers of learners. Using digital simulations allows the creation of approximations of practice for a broad range of educational purposes (several examples from teacher and medical education are described in Fischer and Opitz, 2022). In addition, digital simulations offer many options for automatically adapting the instructional support to relevant learner characteristics (e.g. learners' prior knowledge or current performance; Radkowitsch *et al.*, 2021).

One common form of instructional support is scaffolding, which is meant to enable learners to master a problem-solving task that is currently out of their reach without instructional support (Wood *et al.*, 1976; Tabak and Kyza, 2018). For the context of simulation-based learning, we suggest distinguishing between representational scaffolding and scaffolding directed at the learning process. Scaffolding directed at the learning process poses additional tasks or introduces new elements to the learning situation that learners are asked to perform or consider "on top" of the actual learning task – for example, providing hints and prompts that address the learning process and suggest certain actions or strategies on a cognitive or metacognitive level that aim to facilitate the learning of the main task (e.g. reflection prompts; Bannert and Mengelkamp, 2013). Metaanalytic findings show that additional scaffolding directed at the learning process indeed effectively supports the learning of complex skills with simulations in higher education; however, these benefits are relatively small compared to the effects associated with simulation-based learning itself (Chernikova *et al.*, 2020). The relatively small additional effects found for scaffolding directed at the learning process might be explained by the additional cognitive demands induced by imposing additional elements on the learners (Bannert *et al.*, 2015). The findings pose the question, which mechanisms that take place during the processing of the tasks in simulations can explain these significantly larger effects.

We suggest analyzing what happens at the core of the simulation through the lens of representational scaffolding. Representational scaffolding is implemented in the design of the simulation itself and adjusts the demands of the learning task in simulations by selecting and modifying practice representations to match relevant learner characteristics and learning goals. For novice to intermediate learners (e.g. students in higher education), representational scaffolding might reduce the difficulty of practice representations compared to authentic professional practices (Codreanu *et al.*, 2020). However, in the context of designing further training for advanced professionals, representational scaffolding might as well increase the task difficulty by including desirable difficulties (Bjork and Bjork, 2020). To purposefully select and adjust practice representations, it is necessary to identify relevant features that allow a fine-grained (de-)composition of the variety of potential practice situations and practice representations.

Representational scaffolding in digital simulations of practice situations

In the context of using digital simulations in higher education to facilitate students' learning of knowledge and skills for professional practices, identifying relevant representational features facilitates defining leverage points for representational scaffolding. Representational features are features that allow a decomposition of real-life practice situations as well as representations of practice and, thus, provide an orientation for purposefully selecting and adjusting (i.e. composing) representations of practice for representational scaffolding. Building on research on problem-solving and scientific reasoning (Fischer *et al.*, 2014; Stadler *et al.*, 2019), we suggest four sets of representational features – informational complexity, typicality, agency and situation dynamics (Figure 1) – that serve as a basis for an initial list of representational scaffolds in digital simulations (Table 3).

Informational complexity

The first set of representational features addresses informational complexity. Purposefully incorporating these features into the design of digital simulations can be subsumed as complexity scaffolds.

Research on complex problem-solving suggests considering the amount and connectivity of information inherent to a problem (Stadler *et al.*, 2019; Dörner, 1980). Research on

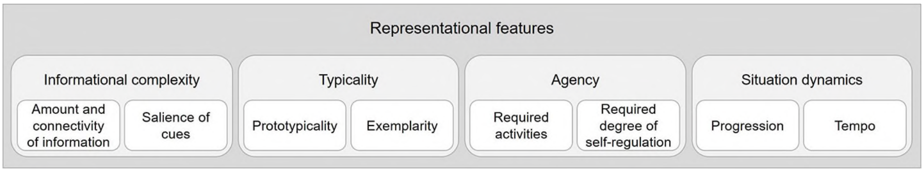

Figure 1. Features of representations of practice offering leverage points for representational scaffolding

Representational scaffold	Range
Complexity scaffolds: representational scaffolds targeting informational complexity	
Adjusting the overall amount of information	few vs many
Adjusting the connectivity of information	isolated vs connected
Adjusting the salience of cues	hyper salient vs nearly realistic
Typicality scaffolds: representational scaffolds targeting typicality	
Adjusting the prototypicality of practice representations	prototypical vs atypical
Adjusting the exemplarity of practice representations	frequent vs infrequent
Agency scaffolds: representational scaffolds targeting agency	
Adjusting the comprehensiveness of required activities	part task vs whole task
Adjusting the required degree of self-regulation to productively interact with the representation	external regulation (to light guidance) vs complete self-regulation
Dynamics scaffolds: representational scaffolds targeting situation dynamics	
Adjusting the progression of situation dynamics	linear vs nonlinear
Adjusting the tempo of situation dynamics	slow vs fast

Table 3. Overview of the suggested representational scaffolds

cognitive load further supports this idea by emphasizing the role of informational connectivity in information processing (i.e. element interactivity; Sweller, 2010): High informational connectivity can increase the cognitive load and might cognitively overwhelm unexperienced problem-solvers. For example, diagnosing a student's thinking in a classroom situation, in which several other students must be monitored in parallel, can be considered more complex than diagnosing a student's thinking in a one-to-one situation. A complexity scaffold in a related simulation might, for example, aim to reduce complexity by letting preservice teachers focus on diagnosing one student at a time.

Research on complex problem-solving, which focuses on abstract and knowledge-lean forms of informational complexity, neglects that different pieces of information can have higher or lower relevance for the adequate processing of a problem. To account for content-related relevance, two different types of information can be distinguished: cues (i.e. relevant information for adequately processing a problem) and distractors (i.e. irrelevant information for adequately processing a problem; Mamede *et al.*, 2012). In real-life practice situations, cues are often not very salient, for example, because of a large number of distractors that limit the prominence of cues (Machts *et al.*, 2021). We thus suggest that the salience of cues in the total amount of information is another relevant aspect of informational complexity. Considering again a classroom situation, teachers who interact with several students in parallel – for example, while leading a group discussion (CPoT 1) – are confronted with extensive information. However, not all the information available in the situation is equally relevant for mastering the situation of leading a group discussion (e.g. irrelevant disturbances that shift the focus away from the actual task of leading a group discussion). To support preservice teachers in their learning of professional practice, using an interactive video-based simulation, in which learners are required to act based on their observations in between watching several video sequences, can be a suitable option. When using filmed sequences of a real-life practice situation, a complexity scaffold might entail reducing distracting information – for example, by omitting a sequence about one student disrupting the group discussion. Another option would be to increase the salience of the relevant cues – for example, by filming a scripted instead of a real classroom situation and thus ensuring that the filmed students clearly follow the relevant behaviors and offer relevant contributions to the group discussion.

By increasing the salience of cues and reducing the amount and connectivity of information inherent to a problem, complexity scaffolds can prevent cognitively overtaxing students who are learning with digital simulations and thus support students' learning of professional practices (Chernikova *et al.*, 2021a).

Typicality

The second set of representational features, which stems from research on scientific reasoning, focuses on the typicality of specific cases or scenarios in a professional field (Papa, 2016). Typicality scaffolds can be used to purposefully incorporate variations of typicality across cases or scenarios into the simulation design. Based on early research on epistemic cognition and reasoning, which distinguished between prototype-based and exemplar-based reasoning (Papa, 2016; Norman *et al.*, 2007), we propose that the typicality of specific cases or scenarios can be defined in terms of prototypicality and exemplarity.

Prototypicality refers to the degree to which a concrete case or scenario matches a blueprint of the related class of cases or scenarios, as it would be described in a textbook (Papa and Elieson, 1993). Prototypicality determines the likelihood that especially novice learners would adequately classify and process the case or scenario. For example, in medical education, clinical encounters of different patients with the same disease may vary, as patients do not necessarily show all the symptoms associated with a disease or may show additional symptoms of more than one disease. Consequently, the patterns of symptoms can vary significantly across patients, ranging from rather prototypical to atypical patterns of symptoms, which can complicate the prioritization of differential diagnoses (core EPA 2). The variations in the possible patterns of symptoms can initially overwhelm medical students. A simulation that aims to support novices' learning of prioritizing differential diagnoses can incorporate typicality scaffolds by selecting and modifying patient cases in a way that the cases involve rather prototypical instead of atypical patterns of the symptoms.

The second notion of typicality is exemplarity, referring to the prevalence of different exemplars of the related class of cases or scenarios within a domain, ranging from frequent to infrequent. Exemplarity determines the likelihood that a professional will gain or has already gained experience with a similar exemplar of a concrete case or scenario. Theoretical approaches to learning and instruction – such as case-based reasoning (Kolodner, 1992) or example-based learning (Renkl, 2014) – emphasize that having gained experience with a problem facilitates the processing of similar problems. For example, diagnosing a rather frequently observed pattern of symptoms will most likely be easier for a physician than diagnosing an infrequently observed pattern of symptoms, as the physician has likely gained more experience with various instances of the frequently observed pattern. When designing a simulation for novice learners in which they are supposed to familiarize themselves with regular cases and scenarios, it might be recommended to initially introduce them to exemplary cases and scenarios they will likely be confronted with when entering real-life fields of practices (Grossman *et al.*, 2009a). The simulation design can use typicality scaffolds by presenting exemplary instead of infrequent cases and scenarios. However, in the context of further training for advanced professionals, it might be desirable to specifically train atypical or infrequent cases (e.g. for the purpose of medical specialization), which might as well be incorporated as typicality scaffold in the simulation design.

Considering both prototypicality and exemplarity seems relevant to a fine-grained decomposition of practice into representations of that practice and, thus, to the purposeful design of simulations by means of representational scaffolding.

Agency

A third set of representational features addresses a professional's agency when engaging in professional practices. Practice situations can differ with regard to the requirements posed to a professional's capacity to act flexibly and adequately in a given situation (i.e. the professional's agency). When designing a simulated representation of a practice situation, the required agency can be adjusted by means of agency scaffolds, which render acting in the simulation more or less challenging for learners.

One aspect that determines the demands associated with taking over agency in a practice situation is the comprehensiveness of the required activities for adequately engaging in the concrete practice situation. There is a range of different conceptualizations for describing the activities required to process a real-life or simulated practice situation, among which are problem-solving activities, epistemic activities and social activities. The conceptualization for describing activities must be chosen and specified corresponding to the practice situation's conceptual structure (Kerr *et al.*, 2016). For example, problem-solving activities – such as planning, executing and monitoring (Liu *et al.*, 2016) – seem to be suitable for describing the general structure of approaching a variety of professional practices (e.g. CPoT 9: setting up and managing small group work; or core EPA 4: entering and discussing orders and prescriptions). In contrast, epistemic activities – such as identifying problems, generating hypotheses, generating and evaluating evidence and drawing conclusions

(Fischer *et al.*, 2014) – seem particularly suitable for knowledge-generating (i.e. epistemic) practices (e.g. CPoT 4: diagnosing particular common patterns of student thinking and development in a subject-matter domain; or core EPA 2: prioritizing a differential diagnosis following a clinical encounter). Besides the cognitive dimension of the required activities, many practice situations in teacher education and medical education also involve a social dimension: teachers often interact with students, parents and other teachers (e.g. CPoT 11: talking about a student with parents or other caregivers), whereas physicians need to interact with patients or their relatives, with other medical doctors of the same or a different specialization or with professionals with different disciplinary backgrounds (e.g. core EPA 1 gather a history and perform a physical examination). Interactive and collaborative practice situations require professionals to engage in not only cognitive but also social activities, such as sharing information, negotiating, regulating collaboration and maintaining social interaction (Liu *et al.*, 2016), which may as well be specified corresponding to the conceptual structure of the concrete practice situation (Kerr *et al.*, 2016). For example, the social activity of regulating collaboration seems particularly relevant for collaborative practices and situations, in which "two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills, and efforts to reach that solution" (OECD, 2017, p. 134; e.g. core EPA 9 collaborating as a member of an interprofessional team). To avoid overwhelming novice learners by having them perform multiple cognitive and social activities, agency scaffolds can be incorporated into the simulation design. Agency scaffolds can adjust the comprehensiveness of the required activities by letting learners focus on some specific parts of the task instead of confronting them with the "whole task" of coping with a real-life situation (van Merriënboer *et al.*, 2002). A simulation that aims to introduce preservice teachers to diagnosing patterns of student thinking (CPoT 4) can put the learners' focus on selected epistemic activities (e.g. generating hypotheses, evaluating evidence and drawing conclusions) but omit other epistemic activities. For example, the activity of identifying problems might be omitted by directly introducing a simulated student as having a problem, such as a misconception.

Besides the required activities, another relevant aspect of agency is the required degree of self-regulation in a practice situation, which refers to the necessity to "flexibly activate, monitor, inhibit, persevere and/or adapt one's behavior, attention, emotions, and cognitive strategies" (Moilanen, 2007, p. 835). The required degree of self-regulation depends on how well the practice situation is pre-structured with respect to the activities involved. A high degree of structuredness might be grounded in a rather limited number of potential activities to choose from in a given practice situation. The number of potential activities can be determined by the situation itself or by the degree of standardization. For example, in the course of increasing digitalization, many hospitals meanwhile switched to using electronic patient records, which increases the standardization of documenting (see core EPA 5) and thus reduces the required degree of self-regulation. In interactive or collaborative situations (e.g. core EPA 9: collaborating as a member of an interprofessional team), the external regulation provided by other agents can also influence the required degree of self-regulation (Järvelä and Hadwin, 2013). For example, collaboration partners might differ with regard to actively making an adequate contribution to processing a situation. High requirements for self-regulation can overtax novices, who may not yet have learned to act with sufficient flexibility (Chernikova *et al.*, 2021b). Agency scaffolds can be used in the simulation design to adjust the degree of required self-regulation to the learners' skills – for example, by selecting a practice situation that involves a comparably low degree of required self-regulation (e.g. simulating the core EPA 5: documenting a clinical encounter and using electronic patient records as part of the practice representations). Another option would be to adjust the external regulation (e.g. in simulating the core EPA 9: collaborating as a member of an interprofessional team) – for example, by incorporating simulated collaboration partners who offer extensive guidance to learners.

Providing agency scaffolds in digital simulations by adjusting the comprehensiveness of the required activities and the required degree of self-regulation can be used to facilitate learners' agency in simulated professional practices.

Situation dynamics

The fourth set of representational features addresses the dynamics of a practice situation that result from the changes in the situation itself over time and not from the professional's (or learner's) intervention (Frensch and Funke, 1995; Stadler *et al.*, 2019). Situation dynamics require a professional (or learner) to figure out how and in which tempo the system (i.e. the practice situation) develops and changes. Adjusting the dynamics of a practice situation for the purpose of a simulation can be considered a dynamics scaffold. The dynamics of a practice situation might vary with regard to its progression and tempo.

The progression subsumes aspects of the stability and predictability of a practice situation: the progression of a system or situation might approximate linearity or involve any nonlinear dynamic. It might also involve sudden changes after reaching a certain threshold or time. For example, during a lesson, students' learning progress and behavior are not only influenced by the teacher's instruction but also by the social interactions between the students, which might require the teacher to adjust the instruction during a lesson (CPoT 6). In designing simulations, dynamics scaffolds can be used to adjust the situation dynamics – for example, to decrease the dynamics of a simulated situation compared to the dynamics a professional would encounter in a real-life practice situation. A simulation in teacher education that targets teachers' instructions for setting up and managing small group work (CPoT 9) might, for example, reduce the role of social interaction between the students and, thus, put a stronger focus on the effects of the teacher's instruction.

Besides progression, the tempo of situation dynamics might also vary across different practice situations: some practice situations involve extremely slow situation dynamics that become only noticeable over time, such as diagnosing the development of students' self-concept. Other practice situations involve a fast tempo and still require identifying the interactions between various situational factors, such as some situations in the classroom or emergency room. A corresponding simulation might use dynamics scaffolds to increase the tempo to, for example, illustrate the long-term effects of various situational factors on students' self-concept over several different occasions. Moreover, dynamics scaffolds might be particularly relevant to decrease the tempo to let learners identify and process different aspects of practice situations in a simulated classroom or emergency room (e.g. in a simulation of core EPA 10: recognizing a patient requiring urgent/emergent care and initiating evaluation/management).

By adjusting the progression and tempo of a practice situation, dynamics scaffolds can guide learners' attention to specific aspects of the simulated case or scenario when learning with digital simulations.

Incorporating an approximation strategy in the design of digital simulations

We assume that the four sets of representational features suggested above – informational complexity, typicality, agency and situation dynamics – provide a terminology for decomposing, selecting and adjusting representations of various practice situations, which facilitates representational scaffolding in digital simulations. The related representational scaffolds can be strategically implemented in digital simulations to design approximations of practice that are suitable and effective for different learners and different learning goals. To systematically implement the representational scaffolds as part of a strategy for approximating practice in digital simulations, at least three dimensions must be considered: the media design, the sequencing strategy and the type and timeframe of adaptation of representational scaffolding in digital simulations.

First, the media design subsumes the question, which technology and media are the best for implementing concrete practice representations in a digital simulation. The options range from using text, visuals, audio or video (Fischer and Opitz, 2022) to augmented and virtual reality (Barteit *et al.*, 2021). As recent metaanalytic findings show, more sophisticated technologies can indeed increase the effectiveness of simulations in higher education (Chernikova *et al.*, 2020). Different media can also be combined to create multimedia representations (Mayer, 2014; Ainsworth, 2014). To choose a suitable media design option, several factors must be considered. Among these factors is the degree to which the media design approximates real-life practice situations, as this influences learners' perception of the simulation's authenticity. However, it is also critical to find a balance between authenticity and the demands imposed on learners by the simulated practice situation (Codreanu *et al.*, 2020; Norman *et al.*, 2012). Therefore, another question that must be considered regarding media design is which representational scaffolds are intended to be implemented. A third factor is the choice of simulation platform (Fink *et al.*, 2021). There might be strategic or practical reasons (e.g. adhering to an already established or available simulation platform) to choose a simulation platform that offers only limited options for technology and media use because of its limited technical capabilities (e.g. no option to use virtual or augmented reality).

A second dimension of the approximation strategy in digital simulations is the sequencing strategy. Simulations often contain more than one representation of practice (i.e. simulated cases or scenarios) to give learners repeated practice opportunities and to confront them with a variety of aspects of professional practice. The necessary variety of practice representations also implies variations regarding the representational features of informational complexity, typicality, agency and situation dynamics. These variations can be strategically used to incorporate the sequencing principle of increasing difficulty (Collins, 2006; Lyons *et al.*, 2017) by arranging the order of the different practice representations to follow a sequence that specifies a range from easy to difficult. A sequencing strategy might be specified, for example, by referring to informational complexity (simple to complex) or typicality (prototypical to atypical).

A third dimension of the approximation strategy in digital simulations consists of the different types and timeframes of adaptation that can be used in digital simulations to adapt representational scaffolds to learner characteristics (Plass and Pawar, 2020). Adaptivity can be implemented by using different timeframes – on the macro, meso or micro level (Tetzlaff *et al.*, 2021). The macro level refers to adapting tasks and learner support, such as representational scaffolding, between different simulations. The second timeframe is on a meso level, meaning that the adaptations of the representational scaffolding are implemented between different practice representations within a simulation. The third timeframe is on a micro level, which means that the representational scaffolding is adapted within one practice representation. Moreover, two types of adaptation can be distinguished, which differ with regard to the agent of the regulation (Fischer, 2001): either the computer implements the adaptation, which is denoted as adaptivity, or the learner or the instructor implements the adaptation, which is called adaptability.

We assume that considering the media design, sequencing strategy and the type and timeframe of adaptation facilitates the systematic implementation of representational scaffolds as part of a strategy for approximating practice in digital simulations.

Examples of representational scaffolding in existing simulation designs

Example of a simulation from teacher education

To illustrate the use of representational scaffolding, the following section presents two examples of existing simulations and an analysis of representational scaffolding in their design. One example from teacher education is a simulation developed in the context of Teacher Moments (Thompson *et al.*, 2019). Teacher Moments offers a platform with several simulations concerning different practice situations, such as having a parent-teacher conference (see CPoT 11: Talking about a student with parents or other caregivers) or in-class diagnosing of a student's thinking and development in a subject-matter domain, such as mathematics (CPoT 4). The case vignettes are presented as texts, animations or video clips. Learners need to take on the role of a teacher and act on the basis of the case information, for example, by writing or recording audio files of their answers in a simulated conversation. For example, one simulated parent-teachers conference concerns a parent, who regards the class as too demanding. This simulated parent-teacher conference is implemented by using scripted video clips of the talking parent, to which learners need to answer as part of the simulated conversation (by recording their response as an audio file) in between watching the individual video clips.

Showing video clips of the simulated parent creates an authentic level concerning the amount and connectivity of information that learners need to process compared to a real parent-teacher conference. However, the scripting of the video recordings facilitates implementing complexity scaffolds in terms of increasing the salience of specific cues in the conversation.

A typicality scaffold consists in the choice of a practice situation with rather high exemplarity because the described case of a parent discussing the demands of the teacher's lessons can be considered as a rather frequent reason for a parent-teacher conference and, thus, might represent a good starting point for novice learners. By comparison, another case vignette of a parent-teacher conference on the platform describes a parent who wants to discuss potential accommodations for their autistic child, which might – despite its relevance – be considered as less frequent compared to the other scenario and, thus, more suited for more advanced learners.

Regarding the required agency, learners in the video-based simulation of a parent-teacher conference need to engage in a range of cognitive as well as social activities while simulating the social interaction with the parent. However, compared to a real-life parent-teacher conference, the activities required in the simulated scenario are reduced. For example, in contrast to a real-life parent-teacher conference, the simulated parent-teacher conference does not require learners to involve in the same amount of planning (Liu *et al.*, 2016). Instead, the simulation allows learners to focus on the actual conversation with the parent, which can be regarded as an agency scaffold.

In terms of situation dynamics, the simulation can be considered as incorporating a dynamics scaffold, because learners have the option to think about their answer before recording it, which decreases the tempo in which participants need to answer compared to a real-life parent-teacher conference.

Example of a simulation from medical education

A second example of a simulation, which was designed for medical education, aims at facilitating medical students' collaboration as a member of an interprofessional team (core

EPA 9) – more specifically the collaborative diagnosing of an internist and a radiologist (Radkowitsch *et al.*, 2022). Within the simulation, learners take on the role of the internist and diagnose several simulated cases of patients having fever of unknown origin. The learners first receive a patient file and then need to share information and hypotheses with a simulated radiologist to justify a specific type of radiological examination. The interaction is simulated by means of an online request form, which is completed by the learner who receives an adaptive response by the simulated radiologist upon submitting the request.

The computer interface used for the simulated patient file and the request form are mostly realistic compared to the computer interface used for a real patient file and radiological request form, resulting in a comparable amount of informational complexity, that is, an authentic level of complexity. One major difference is that in the simulated request form, there are relevant and also less relevant hypotheses, as well as clickable justifications for the request provided along with check boxes, whereas a real request form would require free text production. Providing these options in the simulated request form increases the salience of relevant information and, thus, is a complexity scaffold according to the representational scaffolding framework.

The practice situation involving an internist and a radiologist was recommended by practitioners in terms of exemplarity, because these two medical subdisciplines interact regularly in a hospital. Therefore, the choice of practice situation can be regarded as a typicality scaffold.

Of all the different aspects of collaborative diagnosing of an internist and a radiologist, the request for a specific radiological examination has comparably low requirements in terms of the social dimension of the interaction, because using a request form is a highly structured form of interaction. The social activities are reduced to sharing and eliciting information and hypotheses, excluding some of the more complex social interactions, such as negotiating of meaning (Liu *et al.*, 2016; e.g. whether certain data can really be interpreted as a certain symptom or whether the reduction of uncertainty with respect to a diagnosis through a specific radiological examination is or is not justifying the radiological exposure). The degree of self-regulation, for example, regarding whether or not to consult a radiologist at all and how to approach the radiologist (i.e. by request form or by using other ways, such as making a phone call), is reduced as well. The interaction with the radiologist is highly structured by the request form, leaving only limited degrees of freedom for necessary self-regulation. These degrees of freedom are high with respect to collaborative reasoning processes, that is, which case information to share and whether or not to share hypotheses as well. Therefore, compared to the real-life interaction between an internist and a radiologist, the simulated interaction can be regarded as including agency scaffolds, by simulating and standardizing the radiologist's responses compared to the real-life practice situation.

Regarding the aspect of situation dynamics, the case vignettes have a stable progression without sudden changes in the patients' medical conditions that can occur in real-life patient cases. In addition, test results and responses of the simulated radiologist are immediately available upon learners' submission of the simulated request form. Through the lens of the representational scaffolding framework, this is scaffolding with respect to the tempo dimension of situation dynamics.

Toward a research agenda on representational scaffolding in digital simulations

To facilitate the learning of knowledge and skills for professional practices by using digital simulations and representational scaffolding in medical and teacher education, we suggest building on the CPoT and core EPA sets of professional practices. The proposed representational scaffolds might contribute to facilitating the learning of knowledge and skills for professional practices in digital simulations. Moreover, the suggested representational scaffolds might serve as a language to approach deriving and addressing questions in related research. To explain and predict the effects of representational scaffolding in digital simulations on the learning of knowledge and skills for professional practices, there are several lines of research questions worth being tackled. Below, we outline what we believe are the most important of these questions.

Important questions relate to the extent to which each of the suggested representational scaffolds advances students' learning of engaging in one or several professional practices and whether the effects differ under varying conditions. On a related note, the relative strengths of the effects caused by the different types of representational scaffolds must be systematically investigated to inform the design processes of digital simulations. Related to the question of the relative effectiveness of the different types of representational scaffolds is the question of synergistic scaffolding (Tabak and Kyza, 2018) – that is, to what extent the combinations of different scaffolds increase the benefits of scaffolding for students' learning in simulations. The idea of synergistic scaffolding has not been empirically well supported so far (Tabak and Kyza, 2018); however, the related research can be subsumed as focusing on scaffolds directed at the learning process, which pose additional tasks to the learners, aiming to guide their processing of the actual learning task. Considering that representational scaffolding adjusts the demands of the learning task itself, exploring the idea of synergistic scaffolding in relation to representational scaffolding might yield different and positive effects on students' learning. In addition, identifying the nonfunctional or detrimental combinations of representational scaffolds would also be a highly relevant contribution of research to improving our understanding of designing digital simulations. Moreover, the effects of combining representational scaffolding with scaffolding directed at the learning process would be relevant to research both in terms of facilitating the learning of professional practices and to better understand the commonalities and differences of the mechanisms underlying the effects of the two approaches to scaffolding.

In addition, we currently do not know much about which and how learner characteristics moderate the effects of representational scaffolding on the learning of knowledge and skills for professional practices, potentially resulting in interindividual differences in the effectiveness of representational scaffolds. A related question is which learner characteristics can be used to implement adaptivity in simulations – that is, to which variable(s) should instructional support be adapted to. Promising candidates include motivation, emotions, prior knowledge, cognitive abilities and self-regulation skills (Plass and Pawar, 2020). They might be considered for adaptivity both in terms of in-situ learner states (e.g. interest in practicing with simulated cases, experience of autonomy vs guidance during task completion, prior knowledge relevant to solve the case) as well as more general learner traits (e.g. academic self-concept, approach or avoidance motivational tendencies, social or test anxiety, self-regulatory skills and general cognitive abilities).

Finally, to determine the scope of the emerging framework of representational scaffolding, the question of the findings' generalizability is of particular interest, especially regarding the extent to which the expected positive effects of representational scaffolding can be conceptually replicated across different professional practices and even across different academic domains and fields.

Conclusion

In this conceptual paper, we introduced the idea of representational scaffolding in designing simulations to facilitate students' learning of engaging in professional practice in teacher and medical education. Building on CPoT and core EPAs, we proposed to consider the knowledge and skills needed to engage in core practices as relevant learning objectives in designing curricula for higher education. Such curricula might benefit from simulation-based learning as an instructional strategy.

We conceptualized designing digital simulations for higher education as the process of decomposing, selecting and adjusting representations of practice along four sets of relevant representational features, namely informational complexity, typicality, agency and situation dynamics. This approach, which can be subsumed as representational scaffolding, aims to adjust the demands of the learning task in simulations to match relevant learner characteristics. Representational scaffolds target leverage points for approximating practice – from initially highly scaffolded, via more realistic simulations, to real-life professional practices.

Building on the proposed conceptualizations, we outlined several key questions of a research agenda addressing the effects of representational scaffolding in digital simulations on the learning of professional practices in higher education. Addressing this research agenda may contribute to more theory-based and evidence-based design decisions for simulation-based learning in higher education.

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