Assessment and evaluation of simulation-based learning in higher education and professional training

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Assessment and evaluation of simulation-based learning in higher education and professional training: An introduction

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ABSTRACT

This Special Issue explores assessment and evaluation of simulation-based learning in higher education and professional development from theoretical, methodological, and empirical perspectives. By bringing together nine studies of different disciplines and professions, we aim to increase the knowledge about the design, use and effectiveness of simulations across communities. The nine contributions are critically discussed to identify potentials of simulations across professions and point out weaknesses that need further attention. In this joint endeavour, we reflect on whether and in which situations simulations are effective ways to support professional learning and development.

1. Introduction

Simulations are used as learning environments in very different contexts of vocational education, higher education, and professional training. Hence, research on the design, use and effectiveness of simulation-based learning is scattered. The idea for this Special Issue was born in 2018 at the EARLI SIG 14 'Learning and Professional Development' conference in Geneva, where we noticed an increased number of contributions dealing with simulation-based learning in higher education and different professional domains. This interest led to an invited symposium at the EARLI conference in Aachen titled "Potentials of simulations across professions" in 2019 and finally resulted in launching an open call for papers in autumn 2020. Clearly, we were motivated by gaining more insights into why participants learn what they learn in simulations and how simulation-based learning can be assessed and evaluated. To increase the knowledge about the design, use and effectiveness of simulations across communities, we bring together nine studies of different disciplines and professions in this Special Issue. In a commentary, these nine contributions are critically discussed to identify potentials of simulations across professions and point out weaknesses that need further attention. Future directions are highlighted to find effective ways in supporting professional learning and development.

2. Attractiveness of simulations

Simulations have become attractive learning environments in vocational education, higher education, and professional training across various disciplines (Hallinger & Wang, 2019). They are valued for their richness and authenticity (Chernikova et al., 2020) and therefore are seen as approximations for professional practice (Codreanu et al., 2020; Grossman et al., 2009). Simulations have in common that they substitute and intensify real experiences with guided ones that induce or reproduce substantial aspects of real work situations in an interactive and dynamic fashion (Chernikova et al., 2020; Ellington et al., 1998; Guetzkow et al., 1963; Landriscina, 2013; Sauvé et al., 2007). According to Mislevy (2013), "a simulation emulates some features of actual situations but not others. It may speed up, slow down, change size, or simplify aspects of real-world situations" (p. 108). Moreover, simulations offer a safe and controlled setting, in which learners can make errors that do not result in severe consequences. On the contrary, errors can function as sources for learning (Gartmeier et al., 2008). The realistic scenarios and equipment allow for retraining and practice until participants master the procedure or skill. Simulations can also mitigate ethical tensions and resolve practical dilemmas (Breckwoldt et al., 2014). Thus, simulations can be a way to develop and assess knowledge, skills, and attitudes. However, simulations are not a panacea, and these learning environments are not necessarily a direct bridge between training and the workplace (Rooney et al., 2015).

In general, simulations vary tremendously (Gray, 2002; Ward et al., 2006) pursuing also different objectives. Gaba (2004) distinguished 11 dimensions to categorise diverse applications, such as aims and purposes of the simulation activity; experience level of participants; type of knowledge, skill, attitudes, or behaviours addressed in the simulation. Simulations can be divided in all-human exercises, man-machine exercises, and all-computer exercises (Greenblat, 1973; Mandel, 1987) leading to a distinction between role-playing, gaming, and computer simulations (Feinstein et al., 2002; Lean et al., 2006; Moizer et al., 2009). The latter primarily focus on content and are characterised by the absence of an interpersonal element resulting in a typology of simulations that distinguishes between computer-based and non-computer-based simulations (Lean et al., 2006). The various contexts, target groups, learning goals, simulation features and ways of implementation impose different requirements on the assessment and

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evaluation of simulation-based learning.

3. Challenges in assessing and evaluating simulation-based learning

Simulation-based learning can foster a wide range of learning outcomes from the acquisition of domain-specific knowledge and routines over the development of problem-solving, critical-thinking, and self-regulatory skills, to the development of attitudes, interests and self-efficacy regarding the respective domain (Baker et al., 2017; Breckwoldt et al., 2014; Chernikova et al., 2020; Hallinger & Wang, 2020; Sitzmann, 2011). Considering the effectiveness of simulation-based learning, we distinguish between assessment and evaluation.

An educational assessment includes a systematic approach to reason from how learners respond to particular tasks to claims about what they generally know or can do (Mislevy, 2013, p. 108). Hence, assessment refers to the extent to which the above learning outcomes have been achieved by learners. The assessment of learning can be done outside the simulation in additional tests, which are then often used in pretest-posttest designs (de Klerk et al., 2015). The assessment can also be directly based on learner performance within the simulation. This in-process assessment allows for instant feedback and tailored scaffolding by human facilitators or by intelligent tutoring systems in case of computer-based simulations (Levy, 2013). In simulation-based assessment, simulations are developed particularly for assessment purposes (Levy, 2013; Mislevy, 2013). Hence, assessment can be formative when assessing goal achievement in order to further improve simulation-based learning or summative when aiming at its effects (Baker & Delacruz, 2016). When designing simulation-based assessments, the Conceptual Assessment Framework as part of Evidence-Centred Design (ECD) suggests that any assessment should clarify a) the student model, which comprises variables for expressing the desired learning outcomes on part of the learner, b) the task model that specifies the (simulation) tasks and variables for expressing the learner responses, and c) the evidence model, which bridges the student model and the task model. Depending on the type of simulation, this bridging between task performance and competencies can be based on human coding using scoring rubrics or computer algorithms for automated scoring (Mislevy, 2013).

Educational evaluation includes but usually extends beyond the assessment of learning outcomes. An evaluation strives for a holistic judgement of the advantages and disadvantages of an intervention (Döring & Bortz, 2016) and an understanding of "[.] the causal logic underlying an intervention" (Coldwell & Maxwell, 2018, p. 268) to enhance the quality of interventions (Brunner et al., 2014). Grasping the causal relationships that influence the outcomes of an intervention requires a theoretical modelling (Campbell et al., 2000).

Probably the most widely used approach to modelling learning processes is the 3P-model model by Biggs (1993) and its adaptation for informal workplace learning by Tynjälä (2008, 2013). The 3P-model distinguishes between *presage* (input), *process* and *product* (output) factors. Assessment in the above sense refers to the *product* factor, that is, the learning outcomes. Biggs (1993) defines *product* factors as the educational learning outcomes. Three learning outcomes are commonly accepted: cognitive (e.g., knowledge, understanding, skills), affective (e.g., motivation, interest, self-efficacy, engagement), and regulative (e.g., self-reflection, self-regulation) (Pintrich, 1994; Vermunt & Donche, 2017).

The evaluation of simulation-based learning goes beyond the mere assessment of learning outcomes and extends to the analysis of process factors and presage factors. *Presage* factors include individual factors on part of the learner as well as contextual factors on part of the learning environment. For instance, the effectiveness of simulation-based learning might be dependent on learners' individual prior knowledge or motivation. Contextual factors refer to the design and the actual implementation of a simulation. Factors such as the complexity and authenticity of or the feedback during simulation-based learning, the setting of learning goals and further preparation within a briefing session (Baker & Delacruz, 2016), time on task or the reflection of learning within a debriefing session (Crookall, 2010) clearly influence the effectiveness of simulation-based learning. *Process* factors refer to the dynamics of the interplay of the presage factors during simulation-based learning. The process perspective focuses on the actual activities during simulation-based learning as well as on intra-individual and inter-individual variations in cognitive, metacognitive, motivational, and emotional processes. Furthermore, in collaborative simulation-based learning, social processes such as communicating, trust, division of labour, role taking affect the learning outcomes.

Table 1
Features of contributions: learning context, domain, type of simulation, research approach.

Author	Learning context	Domain	Type of simulation	Approach
Braunstein et al.	Vocational & professional education	Various	Virtual learning simulations	Systematic review study
Duchatelet & Donche	Higher education	Political decision-making	Face-2-face simulation	Longitudinal case study
Hanus et al.	Professional training	Mountain rescue	Simulation manikin	Quantitative multimethod study
Hofmann et al.	Higher education & professional training	Medicine	Various	Scoping review +*
Hühn & Rausch	Higher education	Business	Computer-based simulation	Exploratory multimethod study
Meier et al.	Vocational education	Car mechatronics	Computer-based simulation	Evaluation study
Sellberg et al.	Higher education	Navigation	Computer-based simulation	Ethnographic fieldwork
Soellner et al.	Higher education	Medicine	Simulation manikin	Intervention study
Vermeiren et al.	Higher education	Political decision-making	Face-2-face simulation	Longitudinal survey study

Note. * 'Scoping review + ' = scoping review + qualitative analysis of curricula objectives.

Assessing and evaluating simulation-based learning poses some general challenges:

(1) Selecting the right constructs: What are the most important presage, process, and product factors for a particular question? Regarding the possible individual and contextual factors, there are countless constructs that might have an influence. Their selection should be based on theoretical assumptions and underlying research questions.

(2) Measurement of these constructs: How can these constructs be measured in a reliable and valid way? We recommend applying the principle of triangulation and multiple data sources such as observational data, log data (in case of computer-based simulations), and physiological data or eye-tracking data where appropriate. In any case, one should not rely on self-report data only, particularly when measuring learning outcomes.

(3) Analysing and interpreting the data: What are the proper conclusions and to what extent are they transferable to other contexts? The transferability or domain-specificity of research findings are an ongoing debate, not only in research on simulation-based learning. Hence, carefully designed replication studies across different content domains, different simulation designs, different target groups and so forth would be very informative.

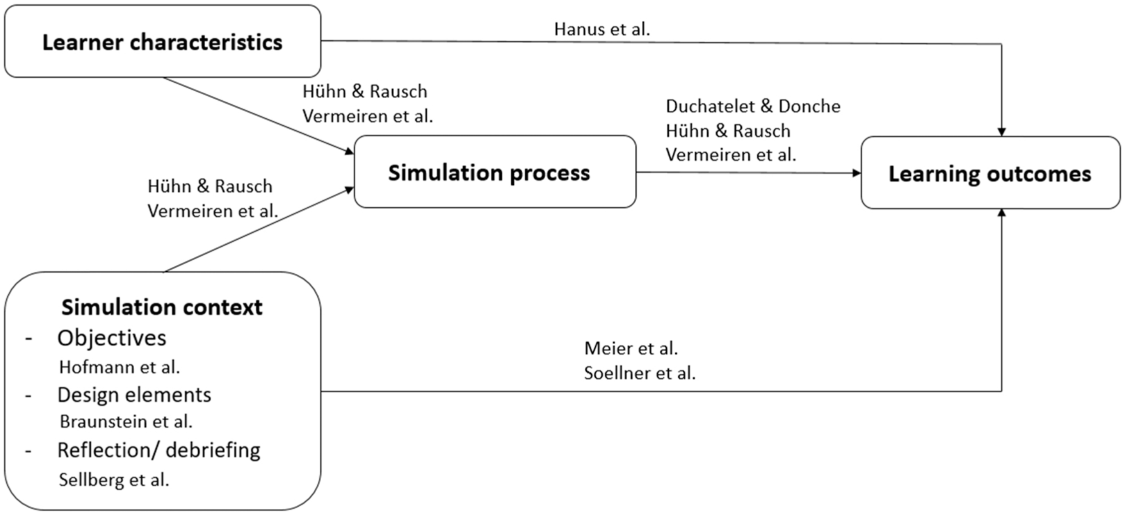

Fig. 1. Overview of the articles in this special issue.

4. Overview of the contributions and overarching themes

This special issue contains nine contributions about simulation-based learning either in the field of vocational education, higher education, or professional training. Features of the different contributions are presented in Table 1.

The different contributions elaborate on one or more factors of the 3P-model, discussed in the previous section, and are presented in Fig. 1.

The study of *Hanus* et al. focuses on the relation between learner characteristics and learning outcomes. More specifically, they elaborate on the assessment of technical and non-technical skills in a mountain rescue simulation taking participant's experience into account.

The papers of *Vermeiren* et al. and *Hühn & Rausch* present learning outcomes of simulation-based learning while taking learner characteristics, simulation design elements, and the simulation process into account. The study of *Vermeiren* et al. applied a longitudinal design to grasp variation in self-efficacy development in relation to learner and simulation features. *Hühn & Rausch* focus on the process of collaborative teamwork and emotions in a management simulation game.

The contribution of *Duchatelet & Donche* elaborates on measuring learning during the simulation process from a methodological perspective. They discuss opportunities and challenges when applying a longitudinal case study design in a several-day role-play simulation. The paper of *Hofmann* et al. also addresses the operationalisation of learning. They conducted a scoping review to increase insights into how to measure non-technical skills in simulation-based medical education, also focusing on the relation with curricular learning objectives.

The papers of *Braunstein* et al. and *Sellberg* et al. examine simulation design elements. Whereas *Braunstein* et al. have conducted a systematic review study resulting in a taxonomy of social embedding in simulation design, *Sellberg* et al. present ethnographic fieldwork that unravel the student-teacher post-simulation dialogue including reflection on and evaluation of student mariner's performance.

Focusing on simulation design elements, *Soellner* et al. present an intervention study investigating the contribution of first-person-view-videos as a feedback tool. The paper of *Meier* et al. elaborate on the development and evaluation of a car mechatronics simulation, focusing on apprentices' diagnostic strategy.

Finally, *Bauer* et al. discuss the different contributions and share interesting insights and ideas about how to forward the field of simulation-based learning research.

Hence, the present Special Issue brings together a variety of studies on simulation-based learning in diverse contexts, aiming at different learning outcomes of various target groups, implementing complex simulation designs, and applying a variety of different methods to collect data regarding the assessment and evaluation of simulation-based learning in vocational education, higher education, and professional training.

Conflict of Interest

We have no known conflict of interest to disclose.

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