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PEDAGOGICAL AND TECHNOLOGICAL FRAMEWORKS FOR SIMULATION-BASED LEARNING

Introduction. Simulation-based learning (SBL) has become widespread across educational programs in many professions. And it seems to be quite natural, as SBL presupposes the creation of “synthetic learning environments” that represent real-life processes or activities and provide a safe surrounding to train in risky or difficult operations to get sufficient practice on in real life operations [1]. The simulated environment allows the instructor to manipulate events and use recorded data (audio, video, or action logs) for educational purposes [2]. Moreover, by engaging students in learning activities, SBL minimizes the “theory-practice gap” [3], which has a great potential in the high-quality specialists training process.

Main part. In order to establish the pedagogical and technological frameworks for SBL, we should first understand what meaning we attribute to simulation. Although universal agreement on its definition is nonexistent, many definitions employ common elements.

The operational definition of simulation includes interaction with a real or virtual object, device, or person and the opportunity to alter the flow of this interaction with the decisions and actions made by learners [4]. It means that, basically, all types of interaction, from role plays to highly immersive interactions with objects of virtual reality, can be considered simulations. Cambridge dictionary states: “Simulation is a model of a set of problems or events that can be used to teach someone how to do something, or the process of making such a model” [5]. Thus, simulation can also be understood as a process (not only the result of a process!) of creating synthetic learning environments. Cook suggests the following, more pedagogical-oriented, definition for the term “simulation”: “educational tool or device with which the learner physically interacts to mimic real life” and in which “the necessity of interacting with authentic objects” is emphasized [6, p. 876].

In the realm of education, simulation-based learning has become a powerful tool indeed. Still, its effectiveness hinges on how it’s designed. From the pedagogical perspective, SBL should be executed taking into account the educational objectives, student’s personality, teacher’s role and technological capabilities at hand. But, most importantly, the mechanisms of knowledge acquisition should be taken into account. We will have a look at some of them.

David Kolb’s Experiential Learning Theory (ELT) posits that learning is a continuous cycle driven by experience, not a passive absorption of information. The model has four stages (which are as well depicted in Figure 1):

1. Concrete Experience (Feeling): Having a hands-on experience.
2. Reflective Observation (Watching): Reflecting on that experience from different perspectives.
3. Abstract Conceptualization (Thinking): Forming abstract concepts or theories based on that reflection.
4. Active Experimentation (Doing): Applying these new ideas to make decisions and solve problems, leading to a new concrete experience.

The theory suggests effective learners need four abilities: being actively involved, reflecting on the experience, using analytical skills to conceptualize, and making decisions to solve problems. Kolb also identified individual learning styles (e.g., Diverging, Assimilating, Converging, Accommodating) that prefer different stages of the cycle [7].

Kolb’s model is a natural fit for simulations. A well-designed simulation directly creates the Concrete Experience. Debriefing and feedback sessions facilitate Reflective Observation and Abstract Conceptualization, helping learners understand why things happened. Finally, the ability to repeat the simulation or try new strategies allows for Active Experimentation, solidifying the learning.

It is also possible to align the simulation approach with the intended learning outcome by applying principles from three foundational learning theories: Behaviorism, Cognitivism, and Constructivism.

Behaviorism views learning as a change in observable behavior, strengthened through stimulus-response associations. This approach is highly structured, relying on reinforcement, practice, and immediate feedback to build accuracy. It is most applicable for teaching foundational skills requiring rote memorization or basic procedures, such as mastering a specific flight checklist or a medical suture technique in a simulated environment.

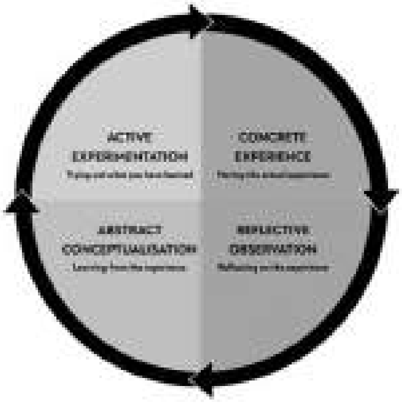

Figure 1 — Kolb's Experiential Learning Cycle [7]

Moving beyond observable behavior, Cognitivism focuses on the internal mental processes of learning — how information is organized, stored, and retrieved. This theory emphasizes active cognitive processing and uses strategies like analogies and advanced organizers to help learners structure knowledge. It is ideal for intermediate tasks that require analysis and reasoning. In simulations, cognitivist strategies enhance conceptual understanding through well-structured scenarios, scaffolding, and feedback that guides mental models.

Constructivism points at learning as an active process where learners construct their own meaning from experiences within authentic, real-world contexts. It emphasizes learner control, collaboration, and reflection. Simulations aligned with constructivism promote collaborative interaction and apprenticeship-style learning, allowing learners to negotiate understanding socially.

Of course, no single theory is superior. Effective instructional design requires an eclectic approach, blending elements from each theory based on the learner's expertise and the task's cognitive demands. Basic skills are built with behaviorist methods, problem-solving is fostered through cognitivist strategies, and complex real-world application is achieved with constructivist principles [8].

If we look at how exactly simulations are used today (from technological point of view), we will observe several trends. Modern SBL utilizes advanced technological tools like Virtual Reality (VR), Augmented Reality (AR), and haptic devices to create immersive, interactive training environments. For example, VR simulators such as Osso VR are used for surgical training, providing medical professionals realistic practice without patient risk. Engineering and design simulators like AutoDesk Fusion 360 allow prototype testing and optimization virtually. Flight simulators like Lockheed Martin Prepar3D replicate real flying conditions for pilot training [9].

Emerging trends include AI-powered adaptive simulations that customize training complexity based on learner performance in real-time. AI chatbots generate dynamic, varied scenarios and provide personalized feedback, making simulations more robust and engaging across fields such as healthcare and customer service training. The convergence of AI with Internet of Things (IoT) and quantum computing is expected to produce highly lifelike, context-aware simulations enhancing realism and efficacy [10].

However, the implementation of SBL faces challenges such as high upfront costs, technology access disparities, and requirement for instructor training. Solutions include scalable cloud-based platforms reducing hardware needs, open-source simulation software, and faculty development programs to bridge technical skills gaps [11].

Simulation learners benefit from active involvement, reflection, problem-solving, and experimentation stages. Instructors serve as facilitators, guiding learners through scenarios, providing feedback, and encouraging collaborative learning. Incorporating learner feedback into simulation design improves relevance and learner satisfaction, making facilitation more effective [12].

Conclusion. Thus, simulation-based learning represents a vital and transformative approach in professional education, effectively bridging the gap between theory and practice. By creating safe, immersive, and interactive environments, simulation allows learners to gain hands-on experience, reflect on their actions, and apply knowledge in realistic scenarios. Its alignment with established learning theories and incorporation of advancing technologies like virtual reality and artificial intelligence enhances both engagement and learning outcomes. Despite challenges such as cost and instructor training needs, ongoing developments and strategic implementation are making simulation increasingly accessible and effective. Ultimately, simulation-based learning not only equips learners with essential skills and confidence but also fosters lifelong professional development and improved performance in complex real-world settings.

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