Towards a Tasks-Interactions-Environment (TIE-SSG) Framework Guiding Integration of Serious Games in Education for Enhanced Practical, Clinical Competences

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Abstract: Clinical skills training is essential but resource-intensive for both educational programs and clinical placement settings. While simulations and serious games (SSGs) show great potential in alleviating skill-training challenges by enabling flexible, interactive, and engaging learning situations in safe environments, difficulties remain in moving beyond their basic implementation and use. The aim of this study is to explore and conceptualize the key elements that form the basis for the proposed Tasks-Interactions-Environment of Simulations and Serious Games (TIE-SSG) Framework. This work aims to initiate discussions and generate ideas that can inform future efforts in developing and refining the proposed framework. The TIE-SSG framework is grounded in instructional scaffolding, and through consideration of these theories and an examination of previous literature, the fidelity (i.e., how closely a scenario or tool mirrors real-world conditions) of the SSGs was chosen as the key factor for the framework. The fidelity term is examined and redefined specifically for introducing SSGs in the context of teaching and learning, and is broken down into three dimensions: tasks, interactions, and environment. The paper illustrates the benefits of examining the fidelity of these dimensions separately, to help place SSGs within the students' learning pathway in a progressive manner. This approach enhances the understanding of how fidelity impacts learning outcomes and provides valuable insights for designing practical learning tools. Future research will further explore how this framework can be applied across diverse educational contexts.

Keywords: Education, Practice-Based training, Simulations, Serious games, Clinical skills and procedures, Learning pathway, Instructional scaffolding, Framework, Fidelity

1. Introduction

Simulations and serious games (SSGs) have shown great promise to support practice-based training (e.g., Mann et al., 2021). SSGs provide learning experiences that are interactive, flexible, varied, and can adapt to the different students' abilities (Ye et al., 2019). It is already demonstrated that SSGs can provide safe training opportunities for providing care to unique-needs patients and contexts (e.g., Scalese et al., 2008). Learning through failing is also a powerful mechanism, made possible through the use of SSGs (Nome, 2022).

Integrating clinical skills training on campus and supervised practice-based training into the learning design of healthcare education is vital, although it is both resource- and time-intensive. Today's education faces challenges in providing sufficient training opportunities due to limited access to real-world settings, time constraints, lack of teaching resources, and restricted availability of equipment. Hence, increasing supervised clinical placements or expanding skills training on campus is not a feasible or sustainable solution. While several educational courses and modules focus on hands-on experience, particularly for learning clinical procedures, these are often challenging to integrate into a traditional curriculum (Mann et al., 2021. As more training would not only enhance the physical and coordinated movements required to perform the task (fine motor skills) but also build confidence, consistency, and adherence to best practices (Arslan et al., 2018), it is important to investigate potential technological solutions to the challenge. Present day SSGs promise to provide high (believable) user experiences and support learning of clinical procedures using a range of technologies, from specialized advanced tools to more widely available devices. There is a wide variety of SSGs, often comprising a range of tools and technologies, making it challenging to decide which one(s) to use, and how to use them, as well as other factors such as considering continuous maintenance for it (e.g., Frøland et al., 2020), application availability, development costs, and creative design (Wang et al., 2014), cognition and presence (Wijkmark et al., 2021), as well as learning goals, content, and societal aspects (Mann et al., 2021).

The aim of this paper is to explore and conceptualize key elements that could form the basis for developing a user-friendly framework that could assist teachers in selecting and implementing SSGs in teaching and learning. The proposed framework also seeks to consider key issues for the further development of suitable applications and provides an overview of essential characteristics of SSGs. The envisioned framework, named Tasks-

Interactions-Environment for Simulation and Serious Games (TIE-SSG), is based on existing frameworks and learning models from current literature utilizing SSGs in education. The methodology considers these frameworks by applying an analytical lens focusing on fidelity for learning and experiences. The usefulness of the framework in education is demonstrated through an example of selecting and utilizing SSGs for practical blood sampling training (Frøland et al., 2025).

2. Background

2.1 Instructional Scaffolding in Skills Training

Instructional scaffolding is a learning theory that concerns assisted guidance of learners, aiming to continuously provide them with tasks that are challenging but doable in order to foster development (Belland and Belland, 2017). The teacher plays an active role in the learning process of the student through means such as providing instructions, hints, and demonstrations. As the student progresses and can do more on their own, the guidance and support from the teacher can be gradually reduced, with the intention of keeping them in an ideal range of challenge. The latter has been coined the Zone of Proximal Development (ZPD) by Lev Vygotsky and is a key influence for instructional scaffolding (Masava et al., 2023). The idea of the ZPD is that the learner is faced with obstacles that are difficult, but achievable, and that the difficulty is gradually adjusted with the help of a teacher or technology. Learners can initially be presented with a situation of limited complexity and then have progressively more complex situations added. Figure 1 shows how the student utilizes various learning resources, including lectures, books, skills training, and SSGs, as part of a learning path facilitated by teachers.

Instructional scaffolding is a well-established principle demonstrated in studies on learning clinical competencies (Masava et al., 2023, Miller, 1990) and in research advocating for SSGs, such as those utilizing virtual laboratories (Ali et al., 2022). Due to the complexity of the student-centered health science education programs, it is crucial to implement varied scaffolding approaches to support learning (Masava et al., 2022). Although instructional scaffolding strategies have been widely explored in general educational contexts, there is a limited understanding of how they can be effectively applied for SSGs in health sciences education.

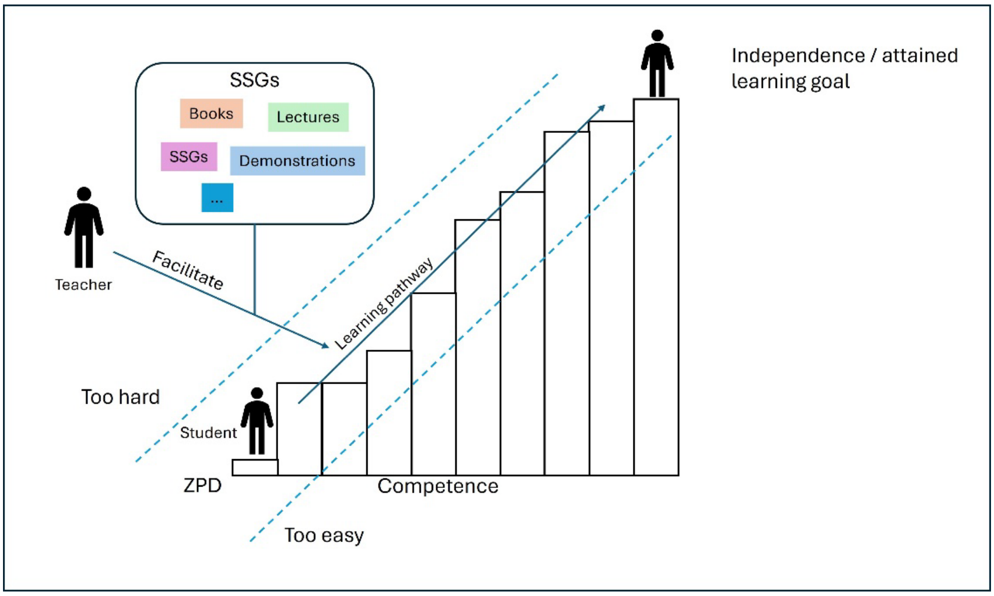

Figure 1: A model conceptualizing the learning environment

2.2 Towards a Framework for Implementing SSGs Through Instructional Scaffolding

Several studies pointed out that the implementation of purposeful use of virtual reality (VR) (e.g., Radianti et al., 2020) and SSGs (Tsekleves et al., 2016, Ravyse et al., 2017) in education is resource-demanding. If, when, and how learning technologies are implemented depends on the type of practices, organizational strategies, and actual policies (Fomin et al., 2024, Attewell, 1992, Badham, 1993). Chugh et al. developed a framework to guide teachers on implementing technology in higher education, incorporating several dimensions like type of technology, stakeholder perceptions, and academic disciplines (Chugh et al., 2023).

Table 1 summarizes the frameworks and models considered in this study.

Table 1: Frameworks and models influencing this study

Framework/Model	Year	Focus	Strengths	Limitations	Applications/Extensions
Technology Acceptance Model (TAM)	1989	Predicting and explaining user acceptance of technologies.	Widely used and adapted to various contexts, including e-learning (Ibrahim et al., 2017).	Inconsistent measurements and challenges in complex situations. Difficult to adjust to changing educational contexts.	Adapted for VR (Huang and Liaw, 2018) and serious games in education (Valencia and Duque, 2023).
Technological Pedagogical Content Knowledge (TPACK)	2005 (revised 2013)	Integration of technology into teachers' educational practices.	Conceptualizes three dimensions: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technology Knowledge (TK), along with their intersections. Helps teachers balance these dimensions for effective practice.	Lacks strategies or guidelines for selecting and using technologies.	Adapted for VR (Polikarpus et al., 2023).
Kirkpatrick's Model	N/A	Differentiates four levels of VR use for learning: user reactions (L1), learning support (L2), behavior change (L3), and societal impact (L4).	Highlights the importance of broader outcomes, from user experience to societal impact.	Connections between the levels in higher education are difficult to establish.	Applied to VR learning, originally developed in 1959 (Alsalamah and Callinan, 2022) and adopted to VR from 1994, according to our knowledge.
TPACK-G (Technological Pedagogical Content Knowledge Games)	2013	Integration of games into teachers' educational practices.	Introduces game-specific dimensions: Game Knowledge (GK), Game Pedagogical Knowledge (GPK), and Game Pedagogical Content Knowledge (GPCK). Proficiency in lower dimensions supports higher-level competence.	Does not provide specific steps on how to integrate games into education or when to use them.	Focused on serious games and educational gaming practices (Hsu et al., 2013).
CAMIL	2021	Learning in VR	Defining important cognitive aspects supporting learning	Does not directly assess games and gamification aspects and implementation for technologies.	Adapted for health and clinical education, laboratories (Makransky and Petersen, 2021)

The models and frameworks described in this paper are well known and are also customized to new technologies, in particular for VR and SSGs considered in this study. For example, TAM for VR (Huang and Liaw, 2018) and for serious games in education (Valencia and Duque, 2023), or TPACK for virtual reality (Polikarpus et al., 2023). Hsu et al. proposed the TPACK for games (TPACK-G) framework, focusing on integrating games into teachers' educational practices (Hsu et al., 2013).

2.3 The Role of Fidelity for Simulations and Serious Games

The goal of SSG-based training is to provide high-quality experiences that enable learners to achieve their learning goals. The degree to which these applications provide realistic and satisfactory experiences varies. This section will explore the role of fidelity in delivering high-quality experiences, drawing on influencing theories about fidelity (see Table 2).

Table 2: Overview of papers considering fidelity and influencing this study.

Author(s)	Year	Focus/Definition of Fidelity	Key Findings/Recommendations
Alessi	1988	Fidelity as the accuracy of a simulator replicating the real environment.	Commonly cited definition highlights the importance of realism in simulation training.
Brydges et al.	2010	Progressive increase in realism through instructional scaffolding.	Progressive realism led to superior transfer of a broad range of clinical skills in simulation-based training.
Hamstra et al.	2014	Reevaluated "fidelity" in simulation-based training.	Recommendations: (1) Abandon the term "fidelity" (due to imprecision). (2) Focus on functional task alignment over physical resemblance. (3) Enhance methods to improve learning transfer.
Tun et al.	2015	Fidelity is based on real-world cues and stimuli instead of complete realism.	Proposed three fidelity dimensions: patient, clinical scenario, and healthcare facilities. Highlighted inconsistencies in fidelity terminology and its implications for healthcare education.
Massoth et al.	2019	Comparison of low-fidelity (LF) vs. high-fidelity (HF) simulators for advanced life support.	Both LF and HF groups showed significant improvement in theoretical knowledge. No significant performance differences were observed between the groups.
Ye et al.	2020	General Conceptual Framework of Fidelity (GCFF).	Framework divides fidelity into three dimensions: sensory, conceptual, and psychological fidelity, emphasizing better clarity and assessment of fidelity in applications, especially in VR contexts.
Carey & Rossler	2023	Multi-dimensional fidelity concept, tied to realism in simulation.	Warned against the "fidelity trap," where higher fidelity is assumed to inherently provide better learning. Emphasized meaningful use of realism and the importance of refining fidelity for simulation pedagogy.
Bonfert et al.	2024	Interaction Fidelity Model (IntFi Model).	Introduced a granular definition of fidelity levels and the relationship between the user and the simulation system. Argued that deliberate reduction of fidelity could sometimes be beneficial for learning outcomes.

Alessi's definition of fidelity, which emphasizes how accurately a simulator replicates the real environment, is frequently referenced (1988). There are many investigations into the role of fidelity in training. Brydges et al. performed a study where they investigated an approach to physical simulation-based training with a progressive increase in realism based on instructional scaffolding (Brydges et al., 2010). The results showed that the progressive group had “superior transfer of a broad range of clinical skills”.

In their 2014 paper, Hamstra et al. examined existing literature and reevaluated the use of the term “fidelity” in the context of simulation-based training. They provided three recommendations:

“#1: Abandon the term fidelity”,

“#2: Shift emphasis from physical resemblance to functional task alignment”, and

“#3: Focus on methods to enhance transfer of learning.”

To effectively use SSGs as learning tools, they must align with curricular learning goals. This can occur directly, such as through a realistic simulation that allows students to practice blood sampling. However, as learning theory suggests, training situations should challenge learners by pushing them slightly beyond their current capabilities without causing cognitive overload. The concept of fidelity has been proposed as a measure of how advanced an SSG application or system is. In previous studies, fidelity is often considered as a simple binary or two-dimensional scale, ranging from low to high (Bergmann et al., 2023). While this approach may offer some utility, it oversimplifies the complexity of SSGs, which rely on diverse software and technologies. Therefore, a more nuanced framework is needed to capture the multifaceted nature of fidelity in SSG design and its impact on learning outcomes.

3. Towards Developing a Framework Considering Fidelity by a Student-Centered Approach

The potential for integration of learning theories to guide the placement of SSGs and related technologies within students' learning pathways highlights the need for a structured framework. Such a framework should support a student-centered approach with the overall focus upon the student's progression toward achieving learning goals (Figure 1). Grounding a framework in instructional scaffolding ensures its practical utility in effectively incorporating SSGs into learning environments. While fidelity has been addressed in previous efforts, it is often ambiguously defined or disconnected from its application to learning. For fidelity to hold meaning, it must be clearly defined and aligned with the tool or context in which it is applied.

We propose redefining fidelity in this context as follows: "*Fidelity is the degree to which the SSG application and tool mimics aspects relevant to achieving the learning goal.*" This definition emphasizes a student-centered and learning-goal-oriented approach.

The proposed definition of fidelity represents a shift from traditional definitions, which often focus on the degree of realism or physical resemblance to real-world environments. This redefinition aligns fidelity with instructional scaffolding. Increased fidelity corresponds to the academically relevant complexity while maintaining a focus on enhancing the student's learning experience. This learner-centered definition of fidelity provides a foundation for a framework that relies on learning theories, ensuring alignment between learning goals and a progressive, scaffolded approach to skill acquisition.

4. The Task-Interaction-Environment (TIE-SSG) Framework

The Task-Interaction-Environment (TIE-SSG) Framework is structured around three dimensions: (i) Tasks, (ii) Interactions, and (iii) Environment. Recognizing the significance of each dimension, we propose examining them separately (see sections 4.1-4.2) to evaluate their suitability for achieving the learning goals within a curriculum. Focusing on the dimensions of tasks, interaction, and environment (TIE) is essential, as an SSGs levels of fidelity can vary across each dimension which impacts its potential use. The dimensions of the framework are relative to the identified learning goals. This distinction sets the framework apart from previous�Figure �.

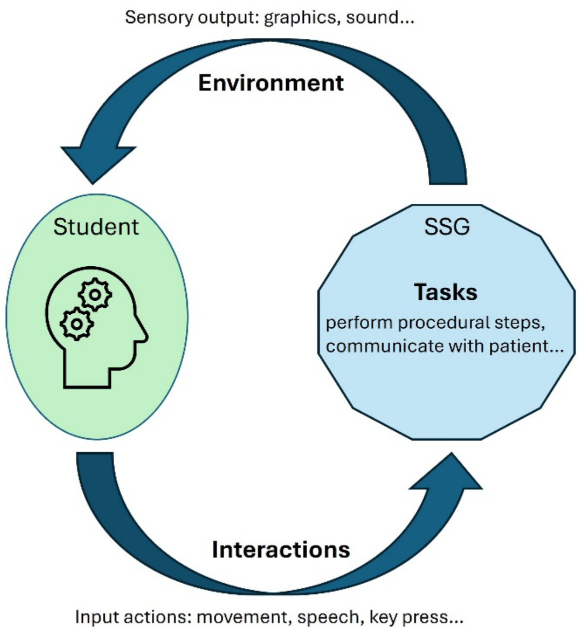

Figure 2: Model depicting the connections between the student and the SSG

4.1 Tasks – and Fidelity

Tasks can be divided into (i) user tasks (actions the learner performs during SSG use) and (ii) SSG-Generated Tasks (tasks designed by the SSG to guide learning) - to fulfil the objective.

User tasks in SSGs involve the specific actions learners perform to engage with the learning environment and achieve objectives. These tasks include executing predefined actions, applying skills in realistic scenarios, solving problems, making decisions, assessing feedback, and role-playing to simulate professional responsibilities. Collaborative tasks are emphasized when the SSG involves teamwork to complete the objective. Assessing feedback is a critical user task in SSGs, requiring learners to actively process and reflect on the information provided by the system, involving understanding successes, identifying errors, and applying necessary corrections to refine performance. By engaging in feedback assessment, learners develop critical thinking skills as they analyze the feedback and make informed decisions to improve their actions, aligning this process with problem-solving and decision-making tasks. Furthermore, assessing feedback fosters the development of metacognitive skills, such as self-awareness and self-regulation, which are essential for mastering complex skills and improving overall learning outcomes. In the context of SSGs, feedback can be assessed in two primary ways: (1) Real-Time Feedback: Learners evaluate immediate feedback, such as performance scores or warning signals during gameplay, and adjust their actions dynamically. (2) Post-Task Feedback: After completing a task or scenario, learners review detailed feedback to reflect on their performance and plan improvements for future attempts. Assessing feedback serves as a crucial bridge between action and learning in SSGs, fostering iterative improvement.

SSG-generated tasks are algorithmically designed activities integrated into SSGs to guide learners through structured learning pathways (Makransky and Petersen, 2021, Mann et al., 2021). These tasks leverage system-driven mechanisms to deliver predefined objectives, adaptive challenges, and scenario-based assignments which can be dynamically tailored to user performance. Key features include progressive difficulty scaling, real-time feedback loops, and achievement tracking through milestone systems. By incorporating guided problem-solving algorithms and role-specific simulations, SSG-generated tasks enable personalized and data-driven instructional experiences

Fidelity in user and SSG-generated tasks: Fidelity is crucial for both user tasks and SSG-generated tasks. For user tasks, such as decision-making, problem-solving, and assessing feedback, high fidelity ensures realistic actions, accurate feedback, and authentic collaboration, fostering critical thinking, metacognitive skills, and practical application — all of which adhere strongly to the learning objectives. In SSG-generated tasks, fidelity focuses on adaptive challenges, realistic scenarios, and system-driven feedback that align with learning goals. By aligning fidelity in both user tasks and SSG-generated tasks, SSGs create immersive and compelling learning environments.

Table 3: Overview of the fidelity focus for each TIE-SSG dimension

Dimensions	Fidelity focus	Examples
Tasks (User)	The tasks performed by the user should mimic the cognitive and physical demands of real-world tasks, striking a balance between complexity and achievability. Task fidelity refers to the degree to which a user's actions align with real-world tasks.	A simulation that requires users to practice drawing blood requires high fidelity for both the physical and cognitive components of the task.
Tasks (SSG)	The tasks embedded in the SSG should align with real-world objectives, while allowing for functional fidelity, focusing on achieving learning goals without replicating every detail of the real world.	An SSG that gradually introduces more complex phlebotomy scenarios may not replicate every detail of an actual phlebotomy, but ensures learners understand the steps and logic needed to respond efficiently.
Interaction	Realistic user actions and feedback loops.	Phlebotomy simulations with realistic tool handling and feedback
Environment	Replicate the physical, visual, and auditory aspects of the real-world setting as closely as necessary for the learning objective.	An SSG for trauma alert at the hospital includes patient beds, medical equipment, and blood collection tools, as well as dynamic and high-pressure scenarios, time constraints, and teamwork and communication, in order to obtain the learning objectives.

4.2 Interaction and Environment – and Fidelity

Interaction

Interaction refers to the ways in which the user can decide, control, or alter the state of the game or simulation. Essentially, it represents the input options available to the user, such as selecting choices, manipulating objects, or navigating through scenarios. High fidelity in interactions means the user's actions closely mimic real-world behaviors or decision-making processes. This includes realistic feedback mechanisms, responsive controls, and intuitive interfaces.

Environment

This dimension consists of all sensory outputs provided to the user, including graphics, audio, and haptic feedback. Fidelity in an environment (environmental fidelity) refers to the degree to which it replicates the physical, visual, and auditory aspects of the real-world setting as closely as necessary to achieve the learning objective. While it could be beneficial to keep the fidelity in this dimension low at earlier stages, in order to reduce cognitive load and to utilize engaging game mechanics, it is crucial to provide high fidelity at the final stages of training to create an immersive and contextually relevant experience. Additionally, ensuring contextual relevance is important; the environment should gradually match the real-world application and align with specific learning goals. For example, replicating a hospital trauma ward for trauma alert training enhances both the authenticity and practicality of the learning experience, ensuring that learners develop the skills needed to meet their educational objectives.

5. Discussion, Current Limitations, and Future Works

The aim of this paper was to introduce the Tasks-Interactions-Environment of Simulations and Serious Games (TIE-SSG) framework. It builds upon key lessons from selected previous frameworks, introducing several novel aspects that make it both practical and learning-focused. First, the framework redefines fidelity by shifting the emphasis toward learning goals, diverging from traditional definitions such as Alessi's (1988). Unlike conventional approaches, the TIE-SSG framework places learning at the centre of fidelity, inspired by works such as Tun et al. (2015), who re-examined fidelity in the context of healthcare education. The framework goes further by explicitly addressing learning goals and aligning fidelity with them. Additionally, it builds on insights from Brydges et al. (2010) by supporting progressive learning but with a more refined focus on its dimensions, allowing for deeper analysis of how SSGs can be effectively utilized.

The TIE-SSG framework is designed to help teachers integrate SSGs into their teaching by providing a structured approach to analysing and reasoning about these tools. By doing so, it supports teachers in gaining deeper insights into SSGs and improving their TPACK level (Ye et al., 2019). A key challenge lies in the time investment required to evaluate SSGs. While this time investment can be justified as necessary for the effective use of any learning tool, it remains a practical consideration that must be taken into account.

Despite its promise, the framework has several limitations. Currently, the TIE-SSG framework primarily focuses on the simulated elements of SSGs and does not explicitly account for game elements. Expanding the framework to include game-specific elements and genres could offer additional value. For instance, varying the types of games suggested to students could provide diverse learning approaches and cater to different student preferences. Offering alternative games for specific steps within the learning pathway could also increase accessibility and engagement.

A systematic literature review of existing frameworks for selecting and using technologies would be valuable for further refining the proposed TIE-SSG framework. While there are reviews in this area, the integration of SSGs into education goes beyond technology acceptance and implementation. Additionally, while some learning goals can be measured objectively, others depend on subjective evaluations. Sharing assessments and feedback with others can help refine and improve these measures, enhancing the framework's utility.

Achieving the right balance of fidelity or aligning user tasks with learning goals cannot be resolved quickly and requires sustained evaluation and adjustment, as supported by Wand et al. (2014) which points out that difficulties are solved by observation over the long term. Moreover, achieving a balance between immersive user experiences and task-specific learning goals is a deliberate design choice. In the near future, the framework will be tested by teachers in ongoing courses and by closer collaboration between teachers and developers to explore how additional features, such as game elements for simulating target procedures, can be effectively integrated. Practical testing of the framework is expected to reveal new insights and areas for refinement, further enhancing its relevance and applicability to real-world teaching scenarios.

6. Conclusions

This paper introduces the initial steps toward developing the Task-Interaction-Environment for Simulation and Serious Games (TIE-SSG) framework, designed to help teachers evaluate and integrate SSGs into education. Rooted in instructional scaffolding as a learning theory, the framework emphasizes fidelity as a key factor, breaking it into its subdimensions focusing on tasks, interaction, and environment (TIE) to support a learner-centered approach. The TIE-SSG framework aims to align SSG usage with learning goals, support instructional scaffolding, and enhance the teaching and learning of clinical skills and procedures while informing further application development.

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