

Challenges of Simulations and Serious Games Embedded in Emergency-Preparedness Platforms and Ecosystems for Educational Use

Ilona Heldal, Rashika Tasnim Keya, Daniel Patel and Tord Frøland

Western Norway University of Applied Sciences, Bergen, Norway

ilona.heldal@hvl.no

rtk@hvl.no

daniel.patel@hvl.no

tohef@hvl.no

Abstract: Simulations and serious games (SSGs) are promising for use in emergency preparedness training, but the challenges of developing them are fundamentally different from those faced in educational use. This paper clarifies this difference by examining an ecosystem including four technology platforms that incorporate SSGs for emergency preparedness (EP) at universities. The paper identifies challenges for SSGs included in platforms and at the ecosystem level, as well as educational challenges, through a multiple-case study involving three engineering courses. We demonstrate how parts of the ecosystem can be integrated into education through collaboration with teachers, the identification of specific observation points aligned with curricular entry points, and the use of selected platform elements. Based on this study, we outline a conceptual framework that shows how design, development, and educational use of SSGs are distinct activities that require different skills for successful use. The results illustrate how the SSGs' technical, systemic, and platform-specific requirements should align with the EP needs outlined by the ecosystem's structure. Future research should explore how this approach can be validated and used in other educational settings.

Keywords: Serious games, Simulations, Emergency preparedness, Platforms, Ecosystems, Higher education, Game-based learning, Socio-technical systems

1. Introduction

Today's emergency preparedness (EP) education at universities faces ongoing challenges in providing adequate training opportunities. Limited access to resources, real-world settings, time constraints, and scarce equipment hinder the ability to offer genuine, hands-on experiences for students and staff. There is a lack of established methods for integrating EP into publicly accessible spaces or into the existing overloaded curricula (Keya et al., 2025, Johnson et al., 2014). Overall, institutional structures often struggle to support cross-disciplinary topics that do not necessarily align with existing topics (Sasie et al., 2026, Demssie et al., 2026). At a higher-education institution, among 392 respondents, 64% had never received information on preparedness, and 68% did not know where the evacuation meeting points were (Carvalhais et al., 2023).

For this paper, "simulations and serious games" (SSGs) refer to various computational simulations that model dynamic scenarios and serious games that incorporate game-based interaction for learning. SSGs can be implemented across diverse technologies: mobile phones, laptops, desktop computers, and virtual reality (VR) head-mounted displays (HMDs), and have demonstrated potential to support practice-based training by facilitating interactive, flexible, and safe learning experiences tailored to students' abilities (Frøland et al., 2025) and promising high levels of engagement, for example, by allowing learners to experience impossible situations, failures, and the consequences of wrong decisions without real harm (Nome et al., 2022). Their use for EP training in higher education remains limited due to difficulties in scaling SSGs to larger educational settings (Keya et al., 2024, Liu, 2024, Hawsawi et al., 2025). Platforms integrating SSGs promise to enhance scalability and contextual relevance (Scalese et al., 2008), but their integration into university education must account for institutional complexity, large student cohorts, rigid curricula, and incompatibilities with local Learning Management Systems (LMSs), which often lack components necessary for EP education. Therefore, embedding EP into the various traditional programs and organizations remains challenging (Mutanda and Ngcamu, 2026).

There are several models and frameworks that promise support for technology implementation in education. This research is inspired by studies emphasizing the importance of context, such as TAM by Davies (1986), the TPACK framework considering pedagogy and teachers' competencies (Koehler et al., 2013), CAMIL for health education (Makransky and Petersen, 2021), understanding situational awareness for experiential learning (Endsley, 2021), and the TRIFECTA model that links organizational rules to IT use (de Vaujany et al., 2017). These studies collectively highlight the need to consider contexts, users, technology, and application variations. However, none of these studies span the combined ecosystem, platform, and SSG levels necessary to know how to support emergency preparedness training, thereby motivating the conceptual framework presented here.

This paper uses these concepts as components of a continuously evolving ecosystem, the *B-prepared* ecosystem, which aims to support emergency preparedness training and learning (European Commission, 2023) through four interconnected open platforms (see further description in Section 2.1) to explore possibilities for EP training through SSGs at universities.

To understand the ecosystem, Adner's (2017) definition is used, where actors, resources, and relations collectively point to value creation, but with distributed control (Iansiti and Levien, 2004) including digital platforms with designed infrastructures enabling complementary innovation (Cusumano et al., 2020) around SSGs and information structures that support skills, knowledge, and competencies required to learn EP. A key role of ecosystems in this context is to utilize continuously evolving platforms with suitable games to avoid path dependency (David, 1985), match needs with possibilities, and keep pace with updates. This sustained variability can prevent lock-in effects and expose educators and learners to adaptable best tools, interfaces, and practices (Garud and Karnøe, 2013), rather than offering static solutions.

The aim of this paper is to illustrate how EP training can be implemented at universities by distinguishing contextual challenges from those of SSGs and platforms. Using the *B-prepared* ecosystem and implementing parts of it across three classes, the paper presents how platform structures and educational practices create requirements for learning EP in higher education institutions. Data come from a multiple-case study of three classes, based on teachers' observations. Points of interest (PoI) for observation were identified, providing a common structure for analysis to suggest possibilities for *teachers* for including SSGs and EP across various courses.

2. Basic Concepts: Ecosystems, Platforms, and Serious Games for Training

This section explains why *B-prepared* can be important for EP education at universities, as well as the roles of ecosystems, platforms, and SSGs in EP classroom education.

2.1 The B-prepared Ecosystem

Training for disaster preparedness as a form of self-help within educational curricula is still an emerging field, and new technologies are increasingly used to motivate students to engage with emergency scenarios. Affordable VR hardware and the expanded use of mobile and web-based applications broaden participation among diverse learner groups, making VR and SSG training possible. Within this landscape, the *B-prepared* ecosystem operates today based on four complementary open platforms: *VR-prepared*, *IM-prepared*, *Disastropedia*, and *RU-prepared*, developed by different organizations but aligned around learning EP.

Each platform offers distinct modules and interfaces: *IM-prepared* provides location-based and remote guided walks through real locations, enriched with puzzles, quizzes, AR games, and contextual information about events such as the Danube flood or the Morandi bridge collapse, with the learning goals to include preparedness via mobile technologies, informed by lessons learned from earlier disasters and incidents. *VR-prepared* offers high-fidelity, immersive, head-mounted display (HMD) and desktop-based simulations of electricity outages, floods, and forest fires to increase presence and engagement in certain contexts. Using *VR-prepared* to improve preparedness is particularly appropriate for cases requiring high levels of immersion. *Disastropedia* serves as a structured knowledge base of incidents, preparedness practices, and advanced preparedness technologies. Like Wikipedia, *Disastropedia* includes illustrations, films, and other media. Finally, *RU-prepared* integrates all components into learning management workflows, enabling students to access training resources, progress through increasingly complex scenarios, and gain information about their individual preparedness. *B-prepared* is designed and developed over the last three years by 15 organizations (project partners).

Together, these platforms create a modular socio-technical environment in which SSGs, knowledge resources, and learning analytics facilitate coordination across organizational boundaries through interoperability. This distributed architecture aligns with Gawer and Cusumano's (2014) view of platforms as modular foundations that support complementary innovation, and Adner's idea of ecosystems (2017). By integrating immersive VR, mobile access, knowledge repositories, and LMS-based orchestration, *B-Prepared* maintains technological diversity and continuous renewal, enabling EP training to evolve dynamically, address varied pedagogical needs, and support scalable, multi-platform learning experiences across universities and professional settings.

2.2 Ecosystems

Ecosystems represent the macro-level socio-technical environment in which SSGs (from different platforms) and various actors interact (David, 1985, Iansiti and Levien, 2004, Jacobides et al., 2018). Table 1 includes the basic

categories considered in the ecosystems, their descriptions, and thoughts motivating their use in this context (see Table 1).

Table 1: Basic components of an ecosystem, original descriptions, and possible interpretations for using it at universities

Components	Descriptions	Usage at universities
Actors / Stakeholders	Individuals and organizations participate in the ecosystem.	Teachers, students, IT support, administrative personnel, technology providers, municipalities, and responders.
Governance & Policies	Rules, standards, policies, and institutional frameworks allow and guide education and collaboration.	University policies, municipalities, and emergency-training regulations.
Resources & Infrastructure	Shared data, hardware, and communication networks enable interaction.	Laboratories, servers, LMSs, databases, computers, mobile devices.
Practices & Processes	How actors use and adapt resources for learning and preparedness.	Course alignments, course integration, and collaborative exercises. Pages in <i>Disastropedia</i> .
Interconnections	Flows of data, knowledge, and coordination between platforms and actors.	Data exchange between the platforms of <i>B-prepared</i> , <i>RU-prepared</i> , and university LMSs.

2.3 Platforms

Platforms are meso-level technical and organizational structures that host and connect simulations, serious games, and users. They can be considered part of ecosystems (Tiwana et al., 2010), can include core components of innovation (Gawer and Cusumano, 2014), and can include specific components that motivate usage (Baldwin and Woodard, 2009), as shown in Table 2.

Table 2: Basic components of platforms, original descriptions, and possible interpretations for using them at universities

Components	Descriptions	Usage at universities
Core Architecture	Technical backbone for each platform and the ones that enable modular integration.	Specifically, for the 4 technologies behind each platform. <i>RU-prepared's</i> LMS integration layer.
Modules / Services	Functional units supporting specific tasks or simulations.	<i>VR-prepared</i> , <i>IM-prepared</i> , <i>Disastropedia</i> , <i>RU-prepared</i> .
Interfaces / APIs	Mechanisms for interoperability and data exchange.	Allowing information, SSGs, and their usage on each platform. Compatibility with Canvas or other LMSs.
User Management	Access control, roles, and data tracking.	Student accounts, instructor dashboards, and providing an overview for actors and stakeholders.
Content Repository	Storage and retrieval of learning materials and game data.	<i>Disastropedia's</i> knowledge base.

2.4 Serious-Games

Serious games are digital games that provide high-quality experiences for non-leisure purposes, such as information dissemination, training, and learning. For this paper, we use the acronym simulation and serious games (SSG) to encompass the use of game engines, asset libraries, and interaction toolkits, not necessarily because they include gamification or competition elements (e.g., Messaoudi et al., 2025, Smith and Trenholme, 2009). They are promising technologies that have become foundational in a variety of domains (Michael and Chen, 2005). However, integrating them into education remains difficult. While universities and many organizations have rules and policies for handling emergencies, they often rely on administrative documents or web pages (as in this study), rather than SSGs. Besides technical factors, the usage of SSGs requires that teachers understand, e.g., the cognitive mechanisms, learning objectives, and feedback loops involved (Mayer, 2019). Some basic, synthesized characteristics of SSGs are shown in Table 3. While SSG use is already established in emergency professionals' training (Heldal, Wijkmark, 2017), it is not yet used in civilian training, including formal education (O'Neil et al., 2005, Keya et al., 2026).

Table 3: Basic components of SSGs, original descriptions, and possible interpretations for using them at universities

Components	Descriptions	Usage at universities
Game Mechanics	Rules, goals, levels, and feedback loops driving engagement.	Mainly fire-evacuation tasks, but also some flood evacuations and time-based coordination.
Simulation Fidelity	Realism and accuracy of the modeled environment.	VR-prepared's immersive training scenarios and the AR games on the mobile interfaces of IM-Prepared. High-fidelity illustrations on Disastropedia.
Learning Objectives	Intended outcomes: learn evacuation procedures and how to stay safe.	Successful decision-making during emergency response. This incorporates understanding the platforms and possibilities.
User Interaction	How players engage with the system.	Keypads, joysticks, mobile touch controls, VR gestures.
Assessment & Feedback	Mechanisms for evaluating performance.	Post-game analytics, reflection prompts. User scores for preparedness in RU-prepared.

2.5 Defining a new “Curriculum” for Emergency Preparedness

Educational institutions operate under tight resource constraints and have a societal mission that limits their ability to introduce new courses; in the current economic climate, programs are more often discontinued than expanded (Sasie et al., 2026, Mutanda and Ngcamu, 2026). In European engineering education, a standard course typically involves 10–15 ECTS credits, with 10 credits corresponding to roughly 250–300 hours of student workload. Even a shorter EP module would require more than simply identifying suitable courses: it would also involve defining appropriate content, allocating time slots, and deciding whether to include examinations. Based on our theoretical view of ecosystems as structured sets of interdependent platforms and SSGs, and on the possibilities at our institution, this investigation has three main motivations:

- Providing accessible EP knowledge to students (with parts of *B-prepared*).
- Leveraging technological diversity for engineering education. The ecosystem exposes students to a range of digital technologies.
- Supporting student-driven innovation for new emergency scenarios.

3. Methodology: A Multiple Case Study

To explore how B-prepared can support EP education, we examined the flexibility of the *B-prepared* ecosystem in developing preparedness-related curriculum components that can be integrated into existing courses at Western Norway University of Applied Sciences (HVL). We adopted a multiple-case study design (Yin, 2011), focusing on three engineering courses in which B-prepared elements were introduced. These points of interest (Polis) were derived from Tables 1-3 for further analysis:

- Identifying specific *B-prepared* components used in the course. This Pol requires understanding the parts and possibilities of B-prepared and the platforms.
- Defining the SSG considerations that make these components usable in the course. This Pol connects course requirements from our education to possibilities in the *B-prepared* parts.
- Observing current integration of SSGs into platforms and the broader ecosystem. This Pol concerns integrating the identified part of *B-prepared* into the course (operational issues).
- Observable user experiences during the course activities. This Pol is similar to Pol-3 but focuses on user experiences among teachers and students.
- Identifying which evaluation approaches can be applied in each course. This remains an open issue, since, to our knowledge, no established approach exists for evaluating SSG integrations of this kind.

These courses were voluntary, in small classes (3-25 students), involving predefined “preparedness curricula” (2x2 hours of classwork and 2-3 hours of homework) for each. This paper is a work in progress based on teachers’ observations and experiences (those who implemented *B-prepared*). The courses were:

- Advanced Computer Graphics (DAT253). This course was taught by a researcher involved in the B-prepared project (ecosystem), which enabled alignment of its graphical application focus with selected B-prepared activities. However, the teacher had to stay within predefined learning outcomes, highlighting a common challenge: choosing the right technologies and components. The

course involved 8 students in 2025 and another class of 15 students in 2026. In this course, students participated in a mini hackathon, where they tested out and suggested additional SSG applications.

- Mobile and Distributed Applications (DAT156). This course, which introduced tools and techniques for developing mobile and distributed systems and typically involved 15-25 students, was held in 2025 and 2026. Students explored *IM-prepared* and knowledge with *Disastropedia* and discussed how to integrate gamification and serious-game elements into mobile and distributed applications. Four researchers from three partner organizations of *B-prepared* contributed in 2025, and only one in 2026.
- Special Topics in Computer Science (DAT259) with 3 participants. HVL enables the creation of specialized-interest courses when students require deeper knowledge in certain domains. This course focused on the latest advances in VR and serious games for emergency preparedness and professional emergency response, enabling MSc students to explore relevant theories, methods, and technologies in greater depth in their theses.

4. Emergency Preparedness Curricula Based on the B-prepared Components

The mapping between the parts of B-prepared and the three classes, along with observations around the 5 Pols, guides a structured analysis of the courses based on the ecosystem's structure. This design allowed us to compare how the different courses could accommodate EP content by integrating SSGs from the four platforms into the higher-education curricula (see Table 4), based on the 5 Pols identified.

Table 4: Planned observation around the points of interest (Pols) in the three engineering courses

Examined Dimension	DAT253: Advanced Computer Graphics	DAT156: Mobile & Distributed Applications	DAT259: Special Topics (VR & SG for Preparedness)
1. <i>B-prepared</i> elements, which are [or could be] used:	<i>VR-prepared</i> simulations; selected graphical assets; ecosystem overview Examples for existing disasters.	<i>IM-prepared</i> mobile app; <i>Disastropedia</i> ; examples of gamification; ecosystem overview.	<i>VR-prepared</i> , <i>IM-prepared</i> , <i>Disastropedia</i> ; full ecosystem mapping; state-of-the-art review (e.g., game design, fidelity).
2. SSG from B-prepared is [or could be] important for the selected courses via:	Focus on graphics pipelines, rendering, asset integration, and the constraints imposed by predefined learning outcomes, such as performance and presence.	Mobile interaction design; distributed architecture; gamification elements; accessibility, interoperability. Reflecting on "How to evaluate SSGs?"	Technology choice, scenario design, fidelity vs. usability, SSG pedagogical alignment, cross-platform design. Reflections and examples on evaluations.
3. Integration of SSGs elements:	Limited integration due to the course's scope; emphasis on graphical modules and games.	Examples of integrating mobile apps, knowledge bases, and workflows.	Deep integration: VR, mobile, knowledge base, LMS; ecosystem-level analysis.
4. Observable user experiences	Students explored VR interactions and discussed graphical fidelity, noting differences in the technical constraints allowed by different platforms.	Students engaged with mobile navigation, quizzes, and <i>Disastropedia</i> content; strong interest in evaluating accessibility, interoperability, usability, and UX.	Students evaluated VR/SG experiences; reflected on realism, usability, and relevance to preparedness.
5. [Reflections on] evaluation methodologies	Informal observations, alignment with course goals, and graphical performance considerations (Patel et al., 2026).	Short assignments; in-class discussions; evaluation of mobile SSG accessibility (2025) and usability for a landslide game (2026).	Structured evaluation of VR/SG approaches relevant to course; preparedness-focused assessment.

As the courses were relatively small, an emphasis is put on whether and how integration was possible, rather than on quantitative evaluation outcomes. It is also challenging to directly compare the success factors across the five dimensions among the three courses, since platform integration was still being developed during this period. The concrete examples in the evaluation, including several known issues that hinder usability and user experience, serve as clear design problems that need to be addressed, which students greatly appreciated knowing about.

5. Towards a Framework for an Emergency Preparedness Curriculum (Module) at Universities

5.1 Discussion

5.1.1 Ecosystems

Based on the original elements of *B-prepared* for analyzing the ecosystem through its platforms and SSGs for three courses, some aspects are vital to understand. While the learning objectives of the SSGs, information in *Disastropedia*, *IM-prepared*, *VR-prepared*, and *RU-prepared* clearly state and even measure learning goals, these goals are secondary to the learning objectives outlined in the three engineering courses. However, they remain important for understanding and assessing students' preparedness interests, and for identifying key actors, resources, and relationships to further work on introducing EP with SSGs. The teachers' involvement in *B-prepared* not only provided concrete examples for lectures but also allowed them to utilize the open platform, which, in turn, can help avoid lock-in effects with ready-made technologies or solutions (David, 1985; Cusumano et al., 2020; Garud and Karnøe, 2013). Currently, *B-prepared* operates under a freemium model; all the resources available for this case may change, so these benefits may not be available later. Several ecosystem-related questions were raised after this study; for example, if greater preparedness can be better supported (included) by secondary learning goals, how would the alignments between them and the primary learning goals work more smoothly? How can we map all important EP learning goals to the learning objectives in other courses (after selecting Pol1 and Pol2)? How can teachers (currently, all except DAT156) be more involved in incorporating EP components into their teaching? What is the knowledge they need? While we presented numerous models and frameworks for technology introduction in education (see Section 2.1), none of these address teachers' dual role in fostering transversal societal competencies, since students should know, in addition to EP, other crosscutting areas, e.g., ethics and sustainability.

5.1.2 Platforms

At the platform layers, these modular technologies were developed within their own organizations but were continuously improved and tested by other project members. These improvements included using *VR-prepared* (with compatible platforms and asset libraries), measuring experiences, using non-immersive technologies for accessibility, and fixing issues in the game engine. Regarding *IM-prepared*, the mobile app was expanded to include more preparedness information from participating countries. The location-based "walks" technology (which involves following points of interest or responding to incidents or disasters at specific locations) was also extended to enable distance walks, multiple AR games, and more. *RU-prepared*, the LMS of *B-prepared*, was extended with a scoring mode associated with several natural disasters, thereby continuously improving the integration of the four *B-prepared* platforms. *Disastropedia* includes information not only on disasters and preparedness but also on education, societal warnings, etc. While engagement is measured (mainly through *RU-prepared* tests, though other platforms also offer games and scores), there is a special focus on disseminating usability and user experience test results. However, sometimes inconsistent results were obtained. For example, a class of 9 students assessed a game in *IM-prepared* using the System Usability Scale (SUS) (Brooke, 1996) and obtained a poor score (56%), whereas another group, assessing the game in a different environment, obtained a good score (86%). After reviewing the evaluation's study design, we found that entering games can be complicated. One group had to enter through the *IM-prepared* platform, locate the games, and play them; the other group could access the game with one click. In this case, accessing the game through the platform degraded the game experience, highlighting the need to investigate how to balance ecosystem integration with usability. The questions that arose after using the platforms were more about design issues relevant to the platforms and cognitive issues regarding considering SSGs as a secondary goal of courses, as well as how integrating analytics better supports indicators of usability, engagement, and progression, i.e., the primary goals of the courses.

5.1.3 SSGs in platforms and ecosystems

As we argued in the introduction, the context matters for accepting and using these technologies. Additionally, considering the fidelity, interaction, and feedback loops, learning support and assessment mechanisms are also important. While *B-prepared* allowed for examining specific mechanisms, important issues related to minimum viable products would also be necessary for more in-depth examinations of mechanisms, e.g., hazard recognition and branching decisions, to better calculate preparedness learning outcomes.

5.1.4 Towards a framework supporting ecosystems for emergency preparedness

B-prepared and its parts, including the open platforms and new SSGs, are continuously developing. Issues illustrating enhanced teacher roles in mastering developments that are important for planning new courses are presented in the following framework (Table 5).

Table 5: A framework guiding EP use in future course iterations. Teachers' contributions and possibilities vary across development stages of ecosystems, platforms, and SSGs. Knowing these stages influences how EP can be considered

Stages of Development	Ecosystem	Platform	Serious-Game
Design	Define preparedness learning goals, governance, and shared resources.	Identify modules, APIs, and technical affordances.	Design mechanics, fidelity, scenarios, and feedback aligned with learning goals.
Adaptation	Align content with institutional constraints (ECTS, course goals).	Select and adapt modules to the course context.	Tailor scenarios, difficulty, and interactions to the cohort/course.
Deployment	Coordinate actors; provide access to shared resources for clear examples.	Deploy modules in LMS, VR lab, and mobile app; ensure interoperability.	Integrate game assets, scenarios, and feedback systems.
Use	Facilitate collaboration and cross-platform learning activities.	Support navigation, access, and progress tracking.	Deliver experiential learning through interaction, decision-making, and feedback.
Evaluation	Apply shared evaluation standards and preparedness indicators.	Provide analytics, logs, usability data, and progress data.	Generate performance metrics, scenario outcomes, and reflective feedback for learning.
Iteration	Update resources, refine governance, and adjust curricular strategies.	Improve modules, interfaces, and interoperability.	Revise mechanics, fidelity, and learning objectives.

6. Concluding Remarks and Future Work

This study examined how the *B-prepared* ecosystem, understood as a network of interconnected platforms, can support the integration of EP education into existing higher education curricula. By exploring three courses at a technical university, we demonstrated that the ecosystem's modularity and technological variety enable flexible curricular adjustments, allowing students to learn about preparedness concepts. At the same time, our results highlight structural challenges: limited institutional capacity to develop new courses, predefined learning outcomes, and the additional workload teachers face when incorporating ecosystem-based content. These constraints show the broader challenge of embedding SSG preparedness training into established educational structures.

Future work will extend this investigation by evaluating learning outcomes across multiple cohorts and institutions, examining how different platform combinations influence understanding of preparedness, and exploring how ecosystem-based modules can be scaled or standardized without reducing curricular flexibility. Further research should address generalizability and barriers to long-term adoption, including teacher training, assessment design, and institutional support, to better understand how platform ecosystems like *B-prepared* can sustainably contribute to EP education.

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