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Simulations for Learning in complex scenarios: students' most valued elements.

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Game-based learning is an effective approach to developing learning skills, and simulations play a crucial role in the logistics field by providing realistic and hands-on training. This article presents the findings of a four-year study that investigated students' experiences and perceptions of a Logistics Simulator, known as LOST, used in a logistics undergraduate course for engineering education in Mexico. LOST simulated supply chain operations and aimed to enhance the development of logistical concepts and complex skills. Qualitative data was collected through open-ended questions to assess students' experiences with LOST, involving a total of 216 students across different course cohorts. The responses were analyzed using axial coding to identify the most valued elements of the game-based learning experience with the logistics simulator. The results indicate that students highly valued elements such as the Real World, Decision-Making, Theory in Practice, Learning, Knowledge, Complexity, Experimentation, and Strategies. These findings emphasize the transformative potential of game-based experiences with the simulator, offering innovative and engaging learning opportunities for educational communities, equipping students with crucial decision-making skills, and providing decision-makers with insights into the effectiveness of simulation-based approaches for enhancing learning outcomes and preparing individuals for real-world complex challenges.

Keywords: Game-based Learning, Simulations, Educational Innovation, Higher Education, Complex thinking, Professional Education, XXI Century Skills.

1. Introduction

Game-based learning has been recognized as an effective educational tool that enhances motivation, learning, and knowledge retention while reducing cognitive load and anxiety (Stiller & Schworm, 2019; Vlachopoulos & Makri, 2017).

Simulation-based learning, a form of game-based learning grounded in constructivist learning theory, is particularly effective when connected to real-world topics, especially in science education (Zulfiqar et al., 2019).

While student-centered digital game-based learning is an active area of research, there is a need for better integration of game design and understanding of learning elements and the student's learning environment to fully realize the benefits of digital game-based learning methods (Coleman & Money, 2020). Understanding students' views and experiences with digital games for learning is crucial to ensure the effectiveness of game-based learning pedagogy (Udeozor et al., 2022). However, selecting the most effective serious games for improving learning capabilities and performance can be challenging due to the abundance of techniques and the lack of systematization within game-based learning frameworks (Li et al., 2023). Therefore, it is important to identify the elements that contribute to a satisfactory game-based experience from the students' perspective to guide the design and application of educational technologies.

In the context of logistics education, an assessment was conducted to examine students' perceptions of learning through a simulation-based experience in a logistics undergraduate course for engineering education in Mexico from 2019 to 2022. During the course, students engaged with the Logistics Simulator called LOST (Pacheco-Velázquez & Aguilar-Avalo, 2019; Pacheco-Velazquez & Viscarra-Campos, 2019; Pacheco-Velazquez, 2022), a serious game designed to facilitate the development of logistical concepts and self-directed learning.LOST is an open simulation game that replicates the operations of a small supply chain, where a hypothetical enterprise produces balls for various sports. Through the game, students can grasp logistical concepts and understand their interfaces, as the game demonstrates the impact of decision-making on the overall system performance. It involves decision-making on various aspects of a manufacturing company, such as demand forecasting, production planning, raw material selection, supplier choice, and raw material ordering. Students can observe the consequences of their decisions across different areas of the company within the game.

To evaluate students' experience with LOST, two open-ended questions were used to gather qualitative data regarding overall experience and satisfaction. The responses were analyzed using an axial coding process, which helped identify the most valued elements within the game-based learning experience through the use of the logistics simulator from the students´ perspective. Results provided the basis of a conceptual model for simulation-based learning experiences in higher education.

Educators and designers can benefit from this research, gaining insights into students' perceptions of simulation-based learning. By integrating identified elements, such as immersive decision-making scenarios, into game-based learning, educators can enhance engagement and learning outcomes. Instructional designers can use the study's model to align educational technologies with students' preferences.

2. Game-Based Learning and Simulators

Game-based learning (GBL) is an effective educational approach that utilizes games to engage and motivate students while achieving educational objectives (Krath et al., 2021; Nadolny et al., 2020). GBL provides an immersive environment that encourages exploration, problem-solving, and deeper learning (Krath et al., 2021; Nadolny et al., 2020). It offers cognitive, motivational, emotional, and social benefits, enhancing the overall learning experience (Boyle et al., 2016). As the educational gaming industry evolves, GBL is becoming increasingly important in modern education (Dadure et al., 2021). However, the lack of standardized GBL frameworks and the challenge of selecting the most suitable gamification technique remain areas of improvement (Li et al., 2023).

Game-based learning has proven effective in science education, especially when connected to real-world topics (Stiller & Schworm, 2019). Simulation-based learning, rooted in constructivist learning theory, creates virtual environments where students can collaborate and make decisions in specific scenarios without real-world risks (Zulfiqar et al., 2019). This approach allows students to develop complex skills by simulating real-life situations, overcoming limitations, and providing educational support in simulated professional contexts (Ponce et al., 2022; Chernikova et al., 2020). Simulation frameworks, commonly used in logistics education, optimize real-world simulation problems and improve parameters for simulation methods in industry and business (Hubl & Fischer, 2017). Business simulation games, widely employed in game-based learning, enable users to make decisions, develop management knowledge and complex skills, and understand the consequences of their actions in a risk-free environment (Wang et al., 2020; Barykin et al., 2021). These games are well-received in education, enhancing engagement, decision-making skills, and comprehension of complex logistical situations (Barykin et al., 2021).

To prepare students for the complexities of contemporary business environments and active participation in their communities, higher education institutions need to integrate complex thinking competencies by providing innovative experiences and infrastructure that connect students with real-world contexts (Ramírez-Montoya et al., 2022). Simulations offer valuable opportunities for students to practice and develop complex skills, bridging the gap between theory and practice in a controlled environment (Ponce et al., 2022; Chernikova et al., 2020). By leveraging the power of game-based and simulation-based learning, educators can create impactful learning experiences that prepare students for the challenges they will encounter in their future careers.

Employing qualitative analysis akin to prior studies (Nadolny et al., 2020), our research connects GBL, SBL, and logistics education. This synthesis enriches our comprehension of tailoring educational technology to learners' needs, aligning with pedagogical goals. The study’s amalgamation of theory and empirical investigation propels the discourse on optimizing educational technology for effective learning experiences. The relevance of the present work lies in the need

to understand students' perspectives in simulation-based learning, and its main contributions include empirical insights into student perceptions and the creation of a conceptual model that informs educational technology design. This research enriches the field by providing nuanced perspectives and practical guidance for educators and educational technologists alike.

3. Research questions

RQ1: What are students' perceptions of the educational effectiveness of simulation-based learning experiences in the context of logistics education?

RQ2: Which key elements of simulation-based learning do students consider to be most influential in enhancing their overall learning outcomes within the field of logistics education?

4. Methods

To gather qualitative data on the overall experience and satisfaction with the game, two open-ended questions were used: 1) What I liked the most about the game was... and 2) What I liked the least about the game was... The sample consisted of 216 Mexican industrial engineering students who participated in different cohorts of the logistics course during the August-December and January-May semesters from 2019 to 2022. Convenience sampling was employed, selecting participants based on accessibility and availability to the researcher.

The students' answers to the open-ended questions provided a comprehensive perspective based on their prior reflective process within the framework of their game-based experience during the course.

The analysis of the answers was conducted using axial coding, based on the expressions and words used by the participants, identifying thematic codes that emerged from the transcripts. This included recognizing patterns, explanations, regularities, and recurring themes. Selective coding was then used to integrate and organize the previous codes into a coherent framework. Categories were constructed as conceptual handles to understand the central ideas revealed in the data (Miles and Huberman, 1989).

The emergent categories, among others identified through the analysis, represented the most prevalent themes and concepts that emerged from students' discourse when evaluating the simulator. They provide valuable insights into the aspects of the game that students value the most and offer guidance for further enhancing the design and implementation of simulation-based learning experiences in logistics education.

4. Results

Based on the analysis of students' responses, the results indicate that several categories emerged as the most valued elements of the game-based experience in the analyzed logistics education experience. These categories encompassed key themes and concepts that students consistently highlighted and appreciated.

These most represented categories and their weight in students' discourse when evaluating the simulator can be seen following in Figure 1.

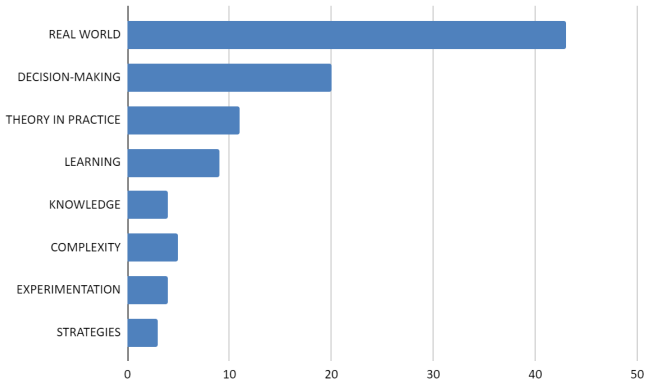

Figure 1. Most represented categories in students' discourse when evaluating the simulator..

One prominent category was "Real World," which reflected students' recognition and appreciation for the simulator's ability to replicate real-world logistics scenarios. "Decision-Making" emerged as another significant category, highlighting the importance of the game in fostering strategic decision-making skills. The category of "Theory in Practice" reflected students' recognition of the game's effectiveness in bridging the gap between theoretical concepts and real-world application. "Learning" and "Knowledge" were two interconnected categories that emphasized the educational benefits of the game-based experience, while "Complexity" was another valued category, as students appreciated the challenging nature of the game and the discipline. The last categories of "Experimentation" and "Strategies" highlighted students' recognition of the game's capacity to experiment with various options and develop their own unique strategies tailored to the logistics challenges presented.

The representation of the aforementioned categories and their most prominent elements by students can be observed in Figure 2.

Figure 2. Representation of categories and their most prominent elements.

Real-World Simulation: Real-world simulations provide students with the unique opportunity to observe and analyze intricate systems, thereby identifying patterns and causal relationships within diverse variables. These simulations serve as invaluable tools for immersive learning, experimentation, and informed strategic decision-making within controlled environments. By mirroring real-world scenarios, they yield crucial insights, optimize strategies, and foster a nuanced understanding of systems across varying contexts, making real-world simulation the most esteemed element among students.

Effective Decision-Making: Rooted in fundamental cognitive processes, effective decision-making involves evaluating multiple options and weighing potential outcomes. Students highly value the acquisition of skills to gather and analyze information, assess risks, and discern potential impacts. Particularly, students underscore the significance of comprehending effects, consequences, impacts, interactions, and analysis within decision-making processes, accentuating its pivotal role in their simulator experience.

Theory in Practice: Bridging the gap between theoretical constructs and real-world scenarios, theory in practice epitomizes the translation of abstract knowledge into actionable strategies. This element resonates profoundly with students, who express deep appreciation for experiences that encompass learning, statistics, knowledge integration, forecasting, and decision-making. The capability to apply theory to practical situations significantly enhances their engagement with the simulator.

Continuous Learning: Learning, an ongoing process involving knowledge, skills, attitudes, and values acquisition, is fueled by diverse means such as observation, experience, and interaction. Students value learning as a central component of their simulator experience, emphasizing the roles of analysis, planning, and practice within this iterative process.

Knowledge Development: Knowledge represents the understanding, information, and skills possessed by individuals, offering a framework for interpreting complex phenomena, solving problems, and interpreting the world. Particularly in logistics domains, such as inventory management, production, forecasts, costs, demand, and delivery, students place high value on knowledge development as integral to their simulator experience.

Complexity: encapsulates interconnectedness in systems, fostering systemic, scientific, critical, and innovative thinking. Among students, the competencies of managing variability, taking diverse actions, and formulating tactical approaches stand out as outcomes of the logistics simulator experience.

Experimentation: serves as a dynamic learning approach that empowers students to explore novel possibilities, discern cause-and-effect relationships, and refine their understanding of the world. Reflective thinking, collaborative interaction, skill refinement, expertise enhancement, organization, and training are highlighted as integral aspects of students' perspectives on experimentation within the simulator.

Strategies: intentional action plans crafted to attain specific objectives, encompassing alternative identification, priority setting, and adaptability to manage complexity and achieve desired outcomes. Students notably emphasize the value of lessons learned, insights gained from mistakes, and core strategies in their simulator experiences, recognizing their pivotal role in achieving successful outcomes.

4. Discussion and conclusions

Delving into students' perceptions of the educational effectiveness of simulation-based learning experiences in the context of logistics education (RQ1), the research findings consistently align with existing literature, establishing a direct correlation between students' positive attitudes towards employing digital games for educational purposes and their cognitive prowess, along with their confidence in navigating game-based learning environments (Udeozor et al., 2022; Zhonggen, 2019). The application of real-world simulations within logistics education affords students an invaluable opportunity to witness and assess intricate systems, formulate strategic judgments, and grasp causal relationships. The present study underscores the significance of realistic scenarios in the Logistics Simulator LOST, demonstrating that students derive the greatest enjoyment from this component due to its provision of insightful information, facilitation of strategic optimization, and deepening of their understanding of diverse systemic operations.

Empirical evidence gleaned from various studies reaffirms that the infusion of games into educational environments catalyzes the cultivation of crucial learning skills, particularly within complex scenarios (Hubl & Fischer, 2017; Lindberg, 2019; Wong & Mok, 2019; Toh & Kirschner, 2020). Regarding key elements of simulation-based learning that students consider to be most influential in enhancing their overall learning outcomes within the field of logistics education (RQ2), results of the present study show that effective decision-making emerges as a highly prized skill among students, underscoring their recognition of the significance of evaluating risks, alternatives, and potential consequences prior to reaching a verdict. Furthermore, games serve as a pivotal medium for honing skills by stimulating engagement, fostering clear observation, and affording opportunities for exploring multifarious strategies (Hallros & Palsson, 2021). This significance is magnified when the chasm between theory and practice is bridged, enabling students to apply theoretical constructs within authentic contexts and make well-founded decisions grounded in data and analysis. Students highly value multifaceted learning encompassing information acquisition, complexity management, experimentation, and strategic acumen.

While the present study explores students' perceptions of simulation-based learning in logistics education, it's crucial to acknowledge inherent limitations. Focusing on a specific course could introduce sampling bias, potentially restricting generalizability. Addressing these challenges enhances the study's credibility and contextual understanding. The findings highlight the considerable impact of simulator-based experiences in providing educational communities with unique and captivating learning opportunities. These experiences provide students with critical decision-making abilities that they will need to participate in society. Furthermore, decision-makers obtain vital information into the effectiveness of simulation-based strategies for improving learning outcomes and preparing individuals to face real-world difficulties. These findings highlight the transformative potential of game-based techniques in providing unique educational pathways and supporting the development of important complex competences.

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