Gamification in Supply Chain Management (SCM) education: a practical experience with the Beer Game

Gamificação no ensino de Gestão da Cadeia de Suprimentos (GCS): uma experiência prática com o Beer Game

Gamificación en la enseñanza de la Gestión de la Cadena de Suministro (SCM): una experiencia práctica con el Juego de la Cerveza

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ABSTRACT
Effective supply chain management is crucial for organizational success, requiring a practical and profound understanding of essential concepts to optimize operations, gain a competitive advantage, ensure customer satisfaction,
mitigate risks, and enable the adoption of innovations that enhance performance. The innovative teaching and learning approach known as gamification, exemplified by the Beer Game, prepares students to face real challenges by simulating a beer supply chain, highlighting its complexity and the "Bullwhip Effect" concept. The practical experience helps students identify the consequences of their decisions, emphasizing the importance of collaboration, coordination, and strategic decision-making. This study aimed to provide 38 students in Technology in Logistics and Bachelor of Administration courses with practical experience in managing a supply chain with variable demand through the Beer Game. The intervention combined theory and practice, using the Beer Game as a simulation tool. Results revealed imbalances in orders and difficulties in decision-making, especially concerning unfulfilled orders. Previously reviewed research has confirmed the effectiveness of the Beer Game as a teaching tool for supply chain management. The evaluation by participating students showed that the game had a significant impact on the development of logical reasoning and the assimilation of concepts, although 25-30% of students faced difficulties in understanding certain game concepts. It is suggested that future Beer Game sessions should include strategies to mitigate the "Bullwhip Effect" and deepen the analysis of decision-making behavior in the supply chain, preparing university students for future challenges in their careers.

**Keywords:** Beer Game, supply chain management, bullwhip effect, simulation, decision making.

**RESUMO**

A gestão eficaz da cadeia de suprimentos é crucial para o sucesso organizacional, exigindo uma compreensão prática e profunda dos conceitos essenciais para otimizar operações, obter vantagem competitiva, garantir a satisfação do cliente, mitigar riscos e possibilitar a adoção de inovações que aprimoram o desempenho. A abordagem de ensino-aprendizagem inovadora conhecida como gamificação, exemplificada pelo Beer Game, prepara os estudantes para enfrentar desafios reais, reproduzindo uma cadeia de suprimentos de cerveja que evidencia sua complexidade e o conceito de "Efeito Chicote". A experiência prática auxilia os acadêmicos a identificar as consequências de suas decisões, ressaltando a importância da colaboração, coordenação e tomada de decisões estratégicas. Este estudo buscou proporcionar a 38 acadêmicos de cursos superiores de Tecnologia em Logística e Bacharelado em Administração uma vivência prática na gestão de uma cadeia de suprimentos com demanda variável, por meio do Beer Game. A intervenção combinou teoria e prática, utilizando o Beer Game como ferramenta de simulação. Os resultados revelaram desequilíbrios nos pedidos e dificuldades na tomada de decisões, especialmente em relação aos pedidos não atendidos. Pesquisas revisadas anteriormente comprovaram a eficácia do Beer Game como ferramenta de ensino para a gestão da cadeia de suprimentos. A avaliação realizada pelos acadêmicos participantes mostrou que o jogo teve um impacto significativo no desenvolvimento do raciocínio lógico e na assimilação de conceitos, embora 25-30% dos estudantes tenham enfrentado dificuldades em entender certos conceitos do jogo. Sugere-se que futuras sessões do Beer Game devam incluir estratégias para mitigar o "efeito chicote" e
aprofundar a análise do comportamento na tomada de decisões na cadeia de suprimentos, preparando os estudantes universitários para os desafios futuros em suas carreiras.

**Palavras-chave:** Beer Game, gestão da cadeia de suprimentos, efeito chicote, simulação, tomada de decisão.

**RESUMEN**

La gestión eficaz de la cadena de suministro es crucial para el éxito de la organización, lo que requiere una comprensión práctica y profunda de los conceptos esenciales para optimizar las operaciones, obtener una ventaja competitiva, garantizar la satisfacción del cliente, mitigar los riesgos y permitir la adopción de innovaciones que mejoren el rendimiento. El innovador enfoque de enseñanza y aprendizaje conocido como gamificación, ejemplificado por el Juego de la Cerveza, prepara a los estudiantes para enfrentar desafíos reales mediante la simulación de una cadena de suministro de cerveza, destacando su complejidad y el concepto "Efecto Látigo". La experiencia práctica ayuda a los estudiantes a identificar las consecuencias de sus decisiones, enfatizando la importancia de la colaboración, la coordinación y la toma de decisiones estratégicas. Este estudio tuvo como objetivo proporcionar a 38 estudiantes de los cursos de Tecnología en Logística y Licenciatura en Administración experiencia práctica en la gestión de una cadena de suministro con demanda variable a través del juego de la cerveza. La intervención combinó teoría y práctica, utilizando el juego de la cerveza como herramienta de simulación. Los resultados revelaron desequilibrios en las órdenes y dificultades en la toma de decisiones, especialmente en lo referente a las órdenes no cumplidas. Investigaciones previamente revisadas han confirmado la efectividad del Juego de la Cerveza como herramienta didáctica para la gestión de la cadena de suministro. La evaluación realizada por los estudiantes participantes mostró que el juego tuvo un impacto significativo en el desarrollo del razonamiento lógico y la asimilación de conceptos, aunque 25-30% de los estudiantes enfrentaron dificultades en la comprensión de ciertos conceptos del juego. Se sugiere que las futuras sesiones del Juego de la Cerveza incluyan estrategias para mitigar el "Efecto Látigo" y profundizar el análisis del comportamiento de la toma de decisiones en la cadena de suministro, preparando a los estudiantes universitarios para futuros desafíos en sus carreras.

**Palabras clave:** Juego de Cerveza, gestión de la cadena de suministro, efecto látigo, simulación, toma de decisiones.

1 **INTRODUCTION**

The effective management of the supply chain plays a crucial role in the competitiveness and sustained success of any organization, regardless of its industry (Gattorna, 2017; Christopher, 2018). Understanding management
processes involves mastering practices, techniques, and strategies essential to achieving desired results efficiently, economically, and successfully in an organization’s administration (Schermerhorn Jr & Bachrach, 2020).

Knowledge of the dynamics involved in a supply chain is fundamental for the success of future managers, providing the skills and knowledge needed to navigate an ever-evolving business environment (Makarius & Srinivasan, 2017). This competence not only strengthens professional capabilities but also prepares individuals to lead confidently in the face of the challenges and complexities of the global market, directly impacting competitiveness and business success (Sanders, 2020).

In higher education, specifically in the field of Management and Business, it is essential for university students to build a solid foundation of Supply Chain Management (SCM) concepts. This is justified as understanding SCM concepts is crucial for optimizing operations, gaining a competitive advantage, ensuring customer satisfaction, mitigating risks, and enabling the adoption of innovations that enhance performance (Jamaludin, 2021). In this context, theory alone often proves insufficient in the face of real-world logistics and inventory management challenges (Salinas-Navarro et al., 2022).

As the business landscape evolves, the methodology used in education needs to innovate, adopting more interactive and practical approaches to better prepare university students for market challenges (Bonfield et al., 2020). Innovative approaches, such as gamification, have gained prominence, as the application of game elements in the learning process has proven to be an effective strategy to engage students, enhance information retention, and promote the practical application of knowledge (Ahmed & Sutton, 2017).

The supply chain encompasses a complex set of processes, ranging from raw material acquisition to the delivery of the final product to the customer (Utama et al., 2022; Christopher, 2018). In the given scenario, understanding logistics principles, inventory management, and the ability to make strategic decisions are essential to optimizing resources, minimizing costs, and responding to demand fluctuations in an agile and efficient manner (Rushton et al., 2022; Soliani et al., 2022).
A methodological approach that can transcend purely theoretical knowledge and involve students in a simulated environment not only enables them to understand but also experience the challenges associated with SCM is simulation. According to Lau (2015), this method provides an active and engaging learning experience, allowing students to internalize the effects of decisions made at different stages of the supply chain. This practical approach allows them not only to understand complex interactions but also to experience the direct and indirect consequences of their decisions. This not only prepares them more comprehensively for real-world challenges but also allows them to tangibly experience concepts presented in the classroom (Jhan et al., 2022).

In this context, the strategic choice to use the Beer Game as a simulation tool for a Supply Chain stands out, providing participants with a highly realistic virtual environment where demand fluctuations, order delays, and coordination challenges manifest concretely (Van den Berg et al., 2017). The Beer Game is a widely used simulation exercise in logistics, management, and supply chain courses, being fundamental for teaching. This tool allows students to experience the real dynamics of a supply chain, highlighting the importance of collaboration, coordination, and strategic decision-making. In the game, participants represent various links in the beer supply chain, managing orders and stocks in search of a balance between supply and demand (Puche et al., 2016).

This experience aims to provide a practical and in-depth understanding of logistical challenges, emphasizing the need for effective SCM. One of the central issues in SCM is the "Bullwhip Effect," a phenomenon where small variations in customer demand can lead to significant amplifications in order fluctuations throughout the chain (Yang et al., 2021). This distortion often arises due to a lack of sharing accurate and real-time information among the chain links (Gomes et al., 2023).

In the face of this challenge, the following question arises: how can we empower students to make strategic decisions in an environment where information is localized and limited, while recognizing that their actions can have substantial impacts throughout the supply chain? In this context, the pedagogical practice of the Beer Game emerges as a means to address this issue, allowing
university students to face, in a controlled manner, coordination, planning, and decision-making dilemmas in a context characterized by fluctuating demand.

The aim of this study was to conduct a pedagogical intervention in SCM courses in the Technology in Logistics program and the Production Management I course in the Bachelor of Administration program at the Rio Branco campus of the Federal Institute of Acre (IFAC), Brazil. During the experience, students were challenged to explore strategies considering the effectiveness of their processes and collaboration between chain components. The emphasis was on balancing local optimization with an understanding that a lack of coordination could result in inefficiencies, problems, and unnecessary costs in the supply chain. Using the Beer Game, university students managed different links in the chain, making complex decisions about demand forecasting, inventory, production, and distribution. The goal was to enable participants to understand how decisions at each stage affect the system as a whole, recognizing the interdependence of activities and demand fluctuations.

2 LITERATURE REVIEW

The effective management of the supply chain is crucial for the competitiveness and success of organizations in all sectors. Understanding the principles of logistics and the ability to make strategic decisions are essential to optimizing resources and responding promptly to fluctuations in demand (De Souza et al., 2023). However, theoretical teaching alone may not adequately prepare students for the practical challenges presented by logistics and SCM (Al-Shammari, 2022).

In this scenario, the learning path represents a pedagogical approach aimed at providing a comprehensive and engaging learning journey in Logistics and SCM. It is an educational strategy that organizes and sequences teaching content to help university students effectively achieve specific learning objectives (Shi et al., 2020). Often, a learning path is customized to meet the needs and skill levels of students, allowing them to progress at their own pace (Vanitha et al., 2019). This approach not only teaches theoretical concepts but also immerses
students in simulated environments, enabling them to experience and understand the practical challenges of SCM (Brazhkin & Zimmerman, 2019).

2.1 GAMIFICATION IN EDUCATION IN SCM

When gamification is integrated into the learning path, as in the case of using the Beer Game, the learning experience becomes even more engaging. Gamification incorporates game elements and motivational structures into learning contexts, encouraging active participation, collaboration, and practical learning (Jayalath & Esichaikul, 2022; França et al., 2023). In the field of Logistics and, specifically, SCM, gamification allows university students to make decisions in highly realistic simulated scenarios where challenges such as demand variations, order delays, and coordination complexity are concretely manifested (Salinas-Navarro et al., 2022).

During the Beer Game, the interaction among supply chain links unfolds as participants, representing different stages, face the task of managing inventory levels and meeting customer demand. Lack of coordination and ineffective communication among these links often result in the so-called “Bullwhip Effect”, where small variations in customer demand trigger exponentially larger fluctuations in orders throughout the chain, highlighting the importance of coordination (Yang et al., 2021). Furthermore, the game challenges participants to make strategic decisions about when to place orders and optimal quantities, developing their strategic decision-making skills in a dynamic supply chain environment.

The combination of the learning path with gamification not only strengthens students’ understanding of the inherent complexities of SCM but also effectively prepares them to face the challenges of Industry 4.0 and the market (Koul & Nayar, 2021). This approach provides a more comprehensive teaching and learning experience, imparting practical knowledge and highly valued skills to university students in the job market.

Gamification plays an essential role in teaching and learning in the field of Management and Business, transforming students’ approach to learning. This strategy involves incorporating game design elements and structures, introducing
gaming practices into contexts that originally had no connection to entertainment (Alsawaier, 2018). It is worth noting that gamification distinguishes itself from traditional approaches, which introduce components devoid of fun into gaming environments, where a task is incorporated into the playful experience (Christopoulos & Mystakidis, 2023). In contrast, gamification does not turn the teaching and learning process into a game but applies the motivational properties typical of games to other teaching activities. This capitalizes on the inherent human desire to share achievements, set goals, and capture the attention of university students, encouraging them to take action (Ge & Ifenthaler, 2018).

Although the term "gamification" originated in the digital media industry, with its first documented use in 2008, its widespread adoption only occurred in the second half of 2010 (Deterding et al., 2011). According to Kwak et al. (2019), it is often confused with other concepts such as "game layer", "applied games", "productivity games", "playful design", or "behavioral games". Essentially, gamification involves applying game elements and principles in teaching and learning contexts to engage students, motivate them, and enhance the educational process. This transforms the teaching and learning experience into something more engaging, interactive, and fun, leveraging the intrinsic motivation often found in games (Saleem et al., 2022).

In the field of education in SCM, we have witnessed significant evolution in recent years. The focus is no longer restricted to purely logistical issues and material movement but has expanded to an increasingly integrated and process-oriented approach, encompassing not only materials but also financial aspects and information exchange (Sinha et al., 2016). This shift transcends organizational boundaries, enabling a more holistic understanding of how supply chains operate, creating a new organizational paradigm (Christopher, 2018).

However, the integration of manufactured components from different locations makes it essential to manage not only the physical movement of goods but also the flow of real-time information. Logistic innovations, such as the Internet of Things (IoT), Artificial Intelligence (AI), Virtual Reality (VR), automation, and information systems, play a central role in this process, providing a comprehensive view of the entire chain (Benešová & Tupa, 2017). Despite the
predominance of traditional teaching and learning methods, recognizing the importance of incorporating these technologies into education represents a fundamental step in preparing the next generation of logistics and SCM professionals (Warmelink et al., 2020).

Thus, gamification emerges as a promising approach to enhance the engagement, interactivity, and effectiveness of teaching and learning in SCM. It provides the opportunity to incorporate game elements and practices, like the Beer Game, into educational environments, promoting active participation, encouraging collaboration, and facilitating practical learning. The integration of gamification into the education of these fields can significantly improve university students’ understanding of inherent complexities, effectively preparing them to face real-world challenges.

2.2 THE BEER GAME SIMULATION IN SCM

The pedagogical intervention proposed in this research is based on a SCM simulation known as the ”Beer Game.” Developed by the System Dynamics Group at the Sloan School of Management of the Massachusetts Institute of Technology (MIT) in the early 1960s as part of Jay Forrester’s research on industrial dynamics, this game has gained a wide range of enthusiasts, from high school students to executive directors and government authorities (Sterman et al., 2015). The structure of the Beer Game replicates the complex purchasing and production decisions in a sequential supply chain composed of four levels: retailer, wholesaler, distributor, and manufacturer. All these links engage exclusively with each other, forming an intricate network in which participants operate over several hypothetical weeks (Wisner et al., 2022).

Each week, players face the challenge of determining the quantity of beer cases they should request from their immediate suppliers, aiming to maintain sufficient inventory to meet customer orders at their subsequent levels while seeking to maximize profit throughout the supply chain (Shovityakool et al., 2019). The game involves four main roles: retailer, wholesaler, distributor, and manufacturer. Each position initially has a beer stock, typically consisting of 12 cases, and is responsible for receiving orders from downstream levels and
fulfilling them while placing orders to upstream levels (Sarkar & Kumar, 2015). Figure 1 graphically outlines this dynamic.

![Figure 1: Supply Chain of the Beer Game](image)

Source: Adapted from Wisner et al. (2022).

Week after week, customers make beer purchases from the retailer, who, in turn, withdraws the necessary beer from its stock (Lau, 2015). The retailer then places orders with the wholesaler, who supplies the requested quantity from its own stock. This process repeats, with orders and deliveries passing through the distributor until reaching the factory, where beer is produced (Sunny et al., 2022).

At each stage, delays in order shipping and processing add additional complexity to the game’s dynamics.

The main goal of players is to minimize the total team costs. Each beer case held in inventory incurs a cost of $0.50 per week. Additionally, when a customer places an order and the player does not have the beer available in stock, this results in an additional backlog cost of $1.00 per case per week (White et al., 2023). This cost represents both lost revenue and dissatisfaction caused by stockouts among customers. It is noteworthy that backlog orders are cumulative, meaning that if a customer is not served in one week, they can be served with the beer that arrives to the player in the following week (Alfieri & Zotteri, 2017). All these costs are considered at each link in the distribution chain.

It is relevant to observe that the Beer Game imposes a crucial restriction: no direct communication is allowed between players, except for the transmission of orders and shipping confirmations (Turner et al., 2020). This limitation adds a layer of complexity to the game, as participants need to make informed decisions...
based on available information, without the benefit of a comprehensive view of the supply chain.

The Beer Game represents a dynamic and educational simulation that captures the inherent complexities of SCM. It is a suitable tool for training professionals and students, preparing them to face market challenges by providing a practical and interactive experience in decision-making within a complex supply chain.

3 METHODOLOGY

The methodology of this research combined theoretical elements with a practical and interactive experience, using the Beer Game as a simulation tool for SCM. The objective was to provide university students in the SCM course of the Technology in Logistics program and the Production Management I course in the Bachelor of Administration program at the Federal Institute of Acre (IFAC), Rio Branco campus, Brazil, with a comprehensive and deep understanding of the inherent challenges in SCM with fluctuating demand through structured stages.

The version used in this activity, played on a board, is available for download from Simulare (2018), a Brazilian company that licenses and provides services related to simulation-based business management solutions, including business games. Simulare’s business games originate from the research group of the Business Games Laboratory of the Department of Production Engineering at the Federal University of Santa Catarina (UFSC).

3.1 DESCRIPTION AND ORGANIZATION OF THE PEDAGOGICAL INTERVENTION

The intervention took place over two days in October 2023, with 20 students from the Technology in Logistics program on the first day and 18 students from the Bachelor of Administration program on the second day. In both sessions, the activity began with a theoretical introduction to the fundamental concepts of logistics, supply chain, and inventory management. Subsequently, the students were divided into groups, each representing a link in the beer supply
During this stage, the rules of the Beer Game were explained, preparing the students for the simulation experience that would follow.

During the game, each group was responsible for managing a specific link in the supply chain (retailer, wholesaler, distributor, or factory). Over 20 consecutive rounds (hypothetical weeks), they made strategic decisions based on local information, facing challenges such as demand fluctuations, order delays, and the inherent uncertainty of the business environment. The activity allowed students to practically experience how their decisions impacted overall outcomes.

After each round, the students gathered for group discussions, analyzing the results achieved, identifying challenges faced, and investigating the causes of variations in stocks and demands. These discussions promoted critical reflection, helping participants understand the interdependence of actions taken by different links in the chain. At the end of the game, a final analysis was conducted, allowing students to share their learnings and insights gained during the process.

To carry out the proposed activity, it was essential to prepare a suitable environment accommodating the students, divided into groups organized in the form of a cell to simulate the stages of a supply chain (retailer, reseller or wholesaler, distributor, and the factory). This organization enabled all chain members to follow the dynamics of the process and understand the interactions between different stages. Additionally, it was crucial to provide students with a theoretical introduction to concepts of logistics, the supply chain, and inventory management before the start of the game, enabling them to understand the fundamental principles applied during the simulation. Lastly, it was important to provide the rules of the game and clear guidelines on its conduct so that participants could adequately prepare for this experience.

3.2 DEVELOPMENT OF THE ACTIVITY

The game was conducted on a board representing the beer production and distribution chain, divided into four stages: retailer, reseller, distributor, and factory (Figure 2). Each sector was managed by a group, where coins
represented beer cases, and post-its symbolized orders between sectors and from the end consumer.

Each round of the game corresponded to one week of simulation. The end consumer, controlled by the facilitator (in this case, professor), made purchases from the retailer, reducing its inventory. The retailer, in turn, sent an order to the wholesaler, impacting its inventory, which, in turn, sent an order to the distributor. The distributor, upon serving the reseller, needed to replenish its inventory and send an order to the factory, which finally produced the beers. At each stage, there were delays (lead time) in the delivery of products, meaning that the order from one round was only available for use in the next round.

The main objective of the game is to minimize costs by optimizing demand fulfillment and inventory management. Storing beer cases from one round to another incurred a cost of $0.50 per case. In case the demand was not met, the cost was $1.00 per unit of unmet demand. Any unmet demand in one round had to be fulfilled in the next round, along with the new demand. Therefore, the
A decision of each sector’s managers involved determining orders based on demand forecasts and the current inventory situation.

To assist in this process, the managers of each chain link had to keep records in a support table after placing orders and serving their customers. It was necessary to determine the available stocks of each sector, as well as the products in transit (TR2 and TR1) and in production (PR2 and PR1). Received orders (PR) also needed to be placed initially — using post-its with quantities. Forwarded orders (PE) did not need to be configured initially. Each step in each round only started when the facilitator (professor) gave the signal.

After this preparation, the participants followed the steps illustrated in Figure 3.

Figure 3: Steps and instructions to play the Beer Game

- **Step 1:** Receive the Product: Retailer, Wholesaler, and Distributor slide the TR2 tokens to Available Inventory. Factory: slides the PR2 tokens to Available Inventory. Retailer, Wholesaler, and Distributor: slide the TR1 tokens to TR2. Factory: slides the PR1 tokens to PR2.

- **Step 2:** Fulfill Orders: Retailer: slide the Available Inventory tokens according to the received order (PR) for the consumer. The Retailer’s order is determined by the mediator and is confidential information. Wholesaler, Distributor, and Factory: slide the Available Inventory tokens according to the received order (PR) for transport (TR1) to their left.

- **Step 3:** Place Order: The Retailer requests the quantity of products from the Wholesaler for the next week, marking the order as PE. The Wholesaler, in turn, does the same with the Distributor, placing the order in PE. The Distributor requests the quantity of products from the Factory for the next week, also marking the order as PE. Finally, the Factory requests the production of products for the next week and records the order as PE. The desired quantity is communicated confidentially, using small pieces of paper to keep the information confidential among the involved sectors.

- **Step 4:** Receive Orders: Retailer, Wholesaler, and Distributor: slide the placed order (PE) to the Received Order (PR). Factory: produces beer by placing more tokens (according to the placed order) in PR1. This step can be performed by the mediator or the participants themselves.

- **Step 5:** Record Moves: Everyone records in the support spreadsheet the placed orders, the final inventory, and the unmet demand for the week.

Source: Authors (2024).

Whenever a new round started, the facilitator placed a new order to the retailer, and the participants returned to Step 1. At the end of the 20 rounds, each sector calculated its costs following the pre-established rules. Additionally, the students participated in a self-assessment through an online form, being invited to justify the scores assigned. This comprehensive evaluation process ensured a
solid and comprehensive analysis of university students’ performance throughout the Beer Game activity.

4 RESULTS AND DISCUSSION

The Beer Game, a widely used game in SCM education, plays a significant role in highlighting the ’Bullwhip Effect,’ a phenomenon characterized by oscillations and amplifications in orders along a chain (Christopher, 2018). This simulation involved 20 students enrolled in the SCM course of the Technology in Logistics program and 18 students enrolled in the Production Management I course in the Bachelor of Administration program at the Federal Institute of Acre (IFAC), Rio Branco campus. The main objective was to explore and illustrate the fundamental principles of this discipline, emphasizing how human decisions directly impact the performance of a supply chain.

During the simulation, participants experienced firsthand the extremes of fluctuations common in a supply chain. The analysis of the results revealed interesting insights into the students’ performance in the Beer Game, going beyond a mere understanding of the concepts involved. Table 1 presents the average values of orders placed, inventories, and unmet demands during the simulation.

Table 1: Average values extracted from the support table of the groups

<table>
<thead>
<tr>
<th>Retailer</th>
<th>Wholesaler</th>
<th>Distributor</th>
<th>Factory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Inventory</td>
<td>Unmet Demand</td>
<td>Order</td>
<td>Final Inventory</td>
</tr>
<tr>
<td>Final Inventory</td>
<td>1</td>
<td>2</td>
<td>4,7</td>
</tr>
</tbody>
</table>

Source: Authors (2024).

The results indicated that manufacturers’ order peaks far exceeded those of retailers, reflecting the imbalance observed in real supply chains, where demand, at certain moments, exceeds the supply capacity, resulting in unfulfilled orders (backorders). These backorders, pending unfulfilled orders (column “Unmet Demand”), can have significant implications for customer satisfaction and supply chain efficiency.

During the activity, a trend was observed in which many participants faced difficulties in their decision-making processes, especially regarding the
management of unfulfilled orders. Many expressed frustration and a tendency to assign blame when confronted with challenges related to fluctuations in SCM. To assist students in understanding demand fluctuations, the professor suggested that groups graphically represent their customer demand estimates, allowing students to visualize and share their perceptions of demand, thereby contributing to more informed decision-making.

However, most participants drew patterns with significant fluctuations, mistakenly associating this cyclical behavior with customer demand. This misconception is understandable, as university students likely attributed fluctuations to some external factor, and in the context of the Beer Game, they may have assumed that fluctuations were direct reflections of variations in customer demand when, in reality, they were consequences of internal challenges within the supply chain itself. The idea that fluctuations can be caused by internal issues in the supply chain, such as lack of coordination or delays, may not have been obvious to them.

A fundamental lesson drawn from the Beer Game experience was the difficulty participants faced in trying to understand the complexity of information feedback and supply cycle time, especially regarding the management of backorders. Most teams struggled to reconcile their order strategies with fluctuations in inventory levels and orders in progress. This often resulted in excessive orders, leading to inventory buildup, while overdue orders remained pending. This observation highlights the critical importance of improving the understanding of system dynamics and the impact caused by delays in supply chain operations, including efficient management of overdue orders to avoid negative impacts on customer satisfaction and supply chain efficiency.

Recent studies in decision-making research using Beer Game simulations have shown that the risk that individual decisions contributing to a collective outcome may be affected by uncertainty in decision-making is a factor contributing to the bullwhip effect (Mohaddesi et al., 2020; Pournader et al., 2023; Thompson & Badizadegan, 2015; Turner et al., 2020). The "Bullwhip Effect" is a common challenge faced in supply chains, where small variations in demand or orders at a
certain point in the chain can lead to significant fluctuations in stocks and orders at subsequent points, creating a chain reaction of imbalance (Yang et al., 2021).

However, this effect is often caused by maintaining additional stocks. Moritz et al.'s (2022) and Sterman and Dogan's (2015) studies show that, due to this instability, individuals are likely to seek larger safety stocks or place orders above what is demanded of them. Figure 4 clearly demonstrates this behavior during the game played with university students from IFAC, with average order values growing along the chain, reaching a 62% difference between the retailer and the factory.

Figure 4: Behavior of average order values along the chain

The study by Alfieri and Zotteri (2017) divided students into two groups, with the first group receiving instructions on the (Q, R) inventory model before the Beer Game simulation, while the second group was instructed after the Beer Game simulation. The (Q, R) model implies continuous stock replenishment, with orders of size Q placed when the inventory level reaches the reorder point R, aiming to minimize the total cost considering ordering, holding, and stockout costs to efficiently balance product availability and costs.

Although the tools of the (Q, R) model couldn't be directly applied to the Beer Game due to differences in demand distributions, the absence of fixed
order costs, and the periodic nature of inventory control in contrast to the continuous (Q, R) model, a decisive concept for operational success demonstrated its relevance: stock position. This concept plays an essential role in effective inventory management (Silva et al., 2022), being transferable and applicable in various scenarios. Students who understood these concepts showed greater proficiency in applying general inventory management principles during the game.

The development of simulation activities replicating real scenarios plays a vital role in providing academics with a solid foundation. These scenario simulations enable educational institutions to assist university students in understanding the practical application of concepts studied in the classroom and effectively assessing the impacts of their decisions, contributing to a comprehensive understanding of inventory management.

Similarly, Lau’s (2015) work introduces a teaching method based on a modified version of the Beer Game designed to help academics tackle SCM challenges. University students participated in the game twice, first in a traditional manner and later, after about 10 weeks of play, developed their solutions to problems related to supply chain structure and logistics management techniques. During the process, instruction and practical application of SCM knowledge played a central role, empowering academics to address future challenges in the field. Most academics provided positive feedback, suggesting the use of similar games in other courses. This modified Beer Game approach promotes students’ autonomous learning, preparing them to solve supply chain problems with an active learning approach.

The study by Sunny et al. (2022) presents the "Blockchain-Enabled Beer Game" (BEBG), a software tool designed to familiarize individuals with the application of blockchain technology in inventory management, a critical component in SCM. Blockchain is a distributed ledger technology that enables secure storage and verification of transactions on a decentralized network of computers. This game adopts the traditional Beer Game scenario and transforms it into a blockchain-enabled environment, creating a decentralized application to demonstrate the tool. Blockchain is a decentralized network, meaning it is not
controlled by a single link in a chain. Each transaction is recorded in a block, and this block is encrypted. In this way, players can experience how each stock-related transaction is protected by the blockchain. While a basic understanding of blockchain fundamentals is necessary, BEBG proves to be a valuable tool for teaching university students the practical use of this technology.

Finally, according to Turner et al.'s (2020) study conducted by the King Ranch Institute for Ranch Management (KRIRM) at Texas A&M University-Kingsville and the South Dakota State University Honors College (SDSUHC), the Beer Game was used as the first exposure of students from these institutions to decision-making in complex systems, filling a gap in agricultural education. The Beer Game revealed the complexities of decision-making in dynamic systems and provided valuable insights into academics' learning and performance.

Turner et al.'s (2020) work analyzed the behavior of a database with over 10 years of Beer Game practices and explored the effects of game dynamics, highlighting both the benefits and challenges of the competition. Additionally, the game was designed to be played twice, emphasizing the importance of continuous learning. The results showed that younger university students tended to adapt their decision strategies more quickly in response to game pressure compared to their older peers, suggesting the importance of flexible approaches in teaching. This study revealed that system dynamics and the use of the Beer Game can provide valuable tools to educate future managers in the field of agriculture, helping address complex challenges of this century.

These studies demonstrate the effectiveness of interactive approaches, such as the Beer Game, in promoting understanding of SCM concepts, emphasizing the importance of comprehending underlying concepts and adapting to complex market dynamics. Furthermore, the incorporation of emerging technologies, such as blockchain, can be valuable in training professionals in logistics and SCM. These research findings offer a comprehensive view of best practices in teaching in this area, also identifying areas that deserve further investigation. Therefore, the Beer Game continues to be a valuable tool for teaching and researching SCM as challenges and opportunities in this field evolve.
4.1 ASSESSMENT OF THE BEER GAME PRACTICE BY PARTICIPATING STUDENTS

The activity had the participation of 38 students, all demonstrating a high level of engagement. After the game’s completion, students were invited to fill out an online questionnaire consisting of 10 questions. The questionnaire aimed to assess how the Beer Game influenced participants’ learning and skills in aspects such as teamwork, practical problem-solving, integration of concepts, and preparation for market situations. It also aimed to evaluate the understanding of SCM and logistics concepts.

The questionnaire’s questions were multiple-choice and presented a response scale ranging from 1 to 7. On the scale, the value 1 represented "Completely disagree", while values 2 to 4 indicated "Neither agree nor disagree – Indifferent". Finally, values 5 to 7 corresponded to "Completely agree". Figure 5 illustrates the responses provided by university students.

![Figure 5: Students' perception of the Beer Game activity](source: Authors (2024)).

It is relevant to highlight that more than 75% of the participants assigned scores of level 5 to 7, indicating complete agreement, for 8 out of the 10 questions. These questions are related to the active contribution of all team members to decisions, integration of concepts from other disciplines during the game, encouragement of practical problem-solving in the work environment, preparation for decision-making in real-world situations, development of
participants' logical reasoning, awakening of critical thinking during decision-making, promotion of teamwork skills development, and contribution to learning SCM and logistics concepts.

All participants fully agree that the game played a significant role in developing participants' logical reasoning and assimilating concepts of SCM and logistics. However, it is important to note that two questions revealed that between 25% and 30% of the academics faced difficulties in understanding certain concepts presented in the game, negatively impacting their ability to play effectively. Furthermore, these participants demonstrated not being fully technically prepared to make decisions related to SCM.

The implementation of the Beer Game in SCM and Production Management I disciplines provided valuable insights into the challenges and complexities faced by real-world supply chains. This highlighted the groups' ability to inadvertently generate inefficiencies within a supply chain and emphasized the importance of addressing biases in decision-making.

For future game sessions, the planning will include exploring strategies to mitigate the so-called "Bullwhip Effect" in the Beer Game and encouraging academics to apply them in a controlled environment. The aim is to deepen the analysis of behavioral aspects of decision-making in the supply chain and continue to emphasize the relevance of the supply system to achieve efficient operations, with the goal of providing university students with a comprehensive understanding of supply chain dynamics, preparing them to successfully face the challenges of their future careers.

5 CONCLUSION

The practice of the Beer Game proved to be an effective tool for illustrating fundamental concepts in the field of SCM. The game allowed for the exploration of the 'Bullwhip Effect,' a common phenomenon causing oscillations and amplifications in orders throughout the chain. This practice simulated the complexity and challenges faced in real supply chains. During the application of the Beer Game to the 38 students, extreme fluctuations were observed, highlighting the significance of human decisions in the supply chain's performance.
Research results revealed that, while more than 75% of participants gave high scores to 8 out of 10 questions in the evaluation questionnaire, indicating full agreement, about 25% to 30% of students faced difficulties in understanding certain game concepts. This underscores the need for a deeper understanding and skills to make informed decisions in SCM. The data showed that the 'Bullwhip Effect' was present, with significantly higher order peaks in the early stages of the chain, reflecting imbalances similar to those found in real-world scenarios.

Furthermore, other related studies emphasized the importance of flexible teaching approaches and the application of emerging technologies, such as blockchain, to prepare university students to tackle the complex challenges of SCM. The Beer Game remains a valuable tool for teaching and research, empowering students to understand concepts and complexities of SCM, preparing them for successful careers in this constantly evolving field. The lessons learned from this simulation provide a solid foundation for the training of future professionals capable of making informed and effective decisions in challenging supply chain environments.
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