



## **GAMIFIED INDUSTRIAL SYSTEMS AS TEACHING AIDS: APPLYING SATISFACTORY GAME TO SUPPORT THE LEARNING OF MECHANICAL COMPONENTS AND ASSEMBLIES**

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**Resumo:** This paper explores the pedagogical potential of *Satisfactory*, a first-person factory-building simulation game, as a gamified platform to support Machine Design education. Eleven undergraduate students from two engineering institutions immersed themselves in the game's environment to identify mechanical systems, components, and assemblies analogous to those studied in the course. Students also correlated these virtual representations with real-world engineering applications experienced during internships. A qualitative approach was adopted, combining guided gameplay with reflective technical reports. The analysis indicates that the game's interactive nature fosters intuitive understanding of concepts such as force transmission, fatigue, interference fits, bolted joints, and dynamic loading. Furthermore, students improved their ability to recognize and articulate the role of mechanical components within broader systems, both virtual and real.

**Palavras-chave:** Engineering Education, Gamification, Machine Design

## GAMIFIED INDUSTRIAL SYSTEMS AS TEACHING AIDS: APPLYING SATISFACTORY GAME TO SUPPORT THE LEARNING OF MECHANICAL COMPONENTS AND ASSEMBLIES

### 1 INTRODUCTION

The integration of gamified digital environments has emerged as a potent strategy in contemporary engineering education, aiming to foster student engagement and deepen understanding of complex concepts (URGO *et al.*, 2022). By embedding game mechanics into learning activities, educators promote motivation and active participation, enhancing knowledge retention (TAKÁCS *et al.*, 2022).

Game-based learning methodologies have proven effective in bridging theoretical knowledge and practical application, especially through simulations and serious games that replicate real-world scenarios (BARTOLOMÉ; VAN GERVEN, 2023; CIGDEM *et al.*, 2024). Such environments cultivate critical thinking, decision-making skills, and provide immediate feedback, essential to the learning process (MARTÍNEZ-MALDONADO, 2025; DAHALAN *et al.*, 2023; JÄÄSKÄ & AALTONEN, 2022).

Simulation-based instruction has been shown to improve students' critical thinking and practical abilities by allowing the application of theoretical concepts to problem-solving contexts (RICO *et al.*, 2023; ORTIZ-ROJAS *et al.*, 2025). In mechanical engineering, educational games have been explored as effective tools to introduce complex topics accessibly, particularly through interactive simulations of mechanical systems (COLLER; SCOTT, 2009; SALEHI *et al.*, 2022).

Building upon these pedagogical advancements, this study investigates the integration of *Satisfactory*, a first-person factory-building and automation simulation developed by Coffee Stain Studios, as a teaching aid in a Machine Design course. Initially released in early access on March 19, 2019, and officially launched on September 10, 2024, *Satisfactory* immerses players in complex industrial environments where they design, build, and optimize production systems (PAPADOPoulos, 2023). As of 2025, the game has sold over 7.9 million copies, reflecting its widespread adoption and relevance (WALES, 2024).

The game's elaborate mechanical assemblies, ranging from conveyors to multi-stage production systems, offer parallels to real-world engineering components and processes. The volume of its user base highlights its potential for educational integration (GORDILLO *et al.*, 2022). By exploring *Satisfactory* industrial systems, students are encouraged to analyze mechanical assemblies intuitively, fostering deeper understanding of machine design principles and promoting the transfer of academic knowledge to professional contexts (KOSMADOURI *et al.*, 2013; PONS-LELARDEUX *et al.*, 2015).

### 2 METHODOLOGY

Machine Design, often referred to as Elements of Machines, is a core discipline in mechanical engineering, focusing on the analysis, selection, and design of components subjected to various loadings (RESHETOV, 1978; BHANDARI, 2010). It combines principles of materials science, mechanics of materials, and failure theories (JUVINALL & MARSHEK, 2020), bridging fundamental knowledge with practical demands in product development and mechanical systems design (SHIGLEY *et al.*, 2020).

The discipline requires integration of concepts from technical drawing, mechanics of solids, materials engineering, general mechanics, and calculus (NIEMANN & WINTER, 2003; NORTON, 2020; MELCONIAN, 1978). Proficiency in modeling, analysis, and problem-solving

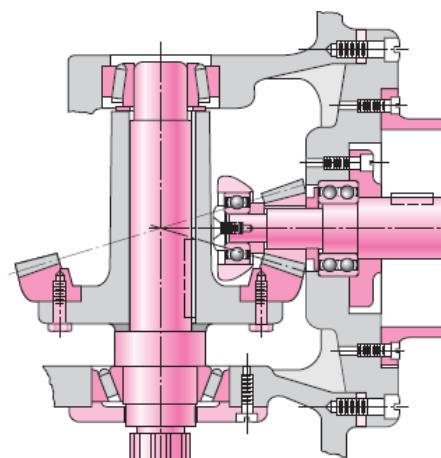
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is essential for addressing real-world engineering challenges (MOTT, 2020; METWALLI, 2010; COLLINS et al., 2009).

At both participating institutions, Machine Design is divided into two sequential courses. The first covers keyed and interference fits, shafts, screws, bolted joints, and fatigue under cyclic loading. The second addresses gears, springs, brakes, clutches, bearings, belt and chain drives, and the application of finite element methods (KAMINSKI, 2000). The curriculum is firmly based on classical references such as Asimow (1962), Dieter & Schmidt (2013), Lesko (2011), and the foundational works previously cited.

These textbooks, adopted globally by leading engineering programs, offer rigorous, structured instruction through validated methodologies and standardized procedures. Figure 1 exemplifies a typical depiction from these references, showing a bevel gear drive with straddle-mounted shafts.

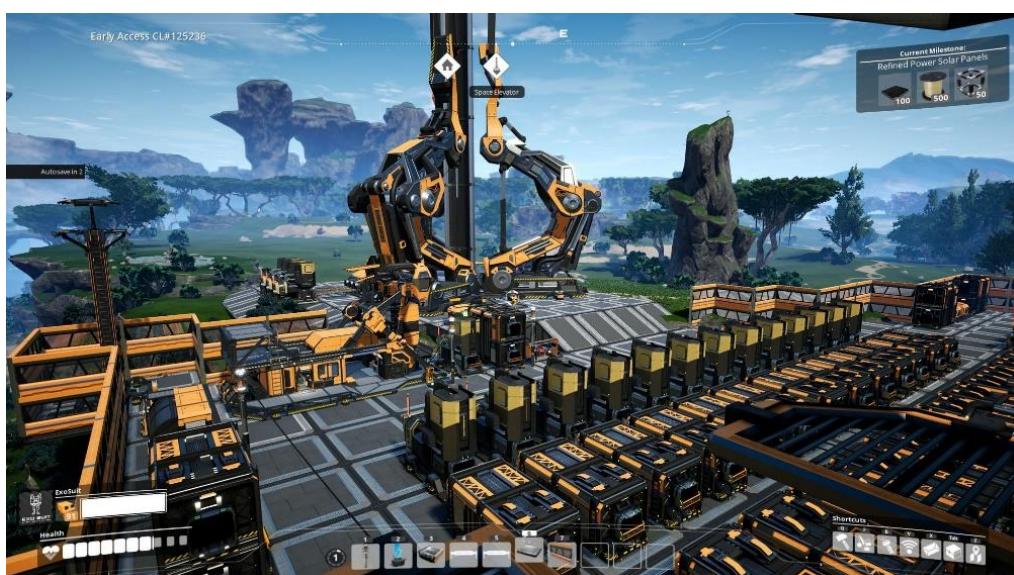
Figure 1 – A bevel-gear drive in which both pinion and gear are straddle-mounted.



Source: Shigley et al. (2020)

Despite the technical richness of traditional texts, they cannot replicate the immersive experience offered by modern simulation-based environments. Games like *Satisfactory* provide dynamic visualization, environmental realism, and interactive manipulation, allowing students to intuitively engage with mechanical systems beyond static illustrations (Figure 2).

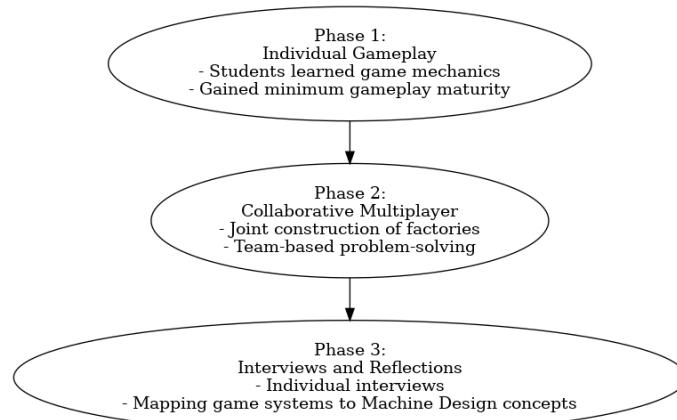
Figure 2 – Game screenshot.



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In this context, an experiment was conducted involving eleven undergraduate students, divided into three phases. Initially, students engaged individually with the game to gain basic proficiency. Subsequently, collaborative multiplayer sessions were introduced to encourage teamwork and systems integration. Finally, semi-structured interviews were conducted, prompting students to correlate in-game mechanical systems with the principles studied in Machine Design. The methodology is summarized in Figure 3.

Figure 3 – Schematic representation of 3-phase didactic experiment.

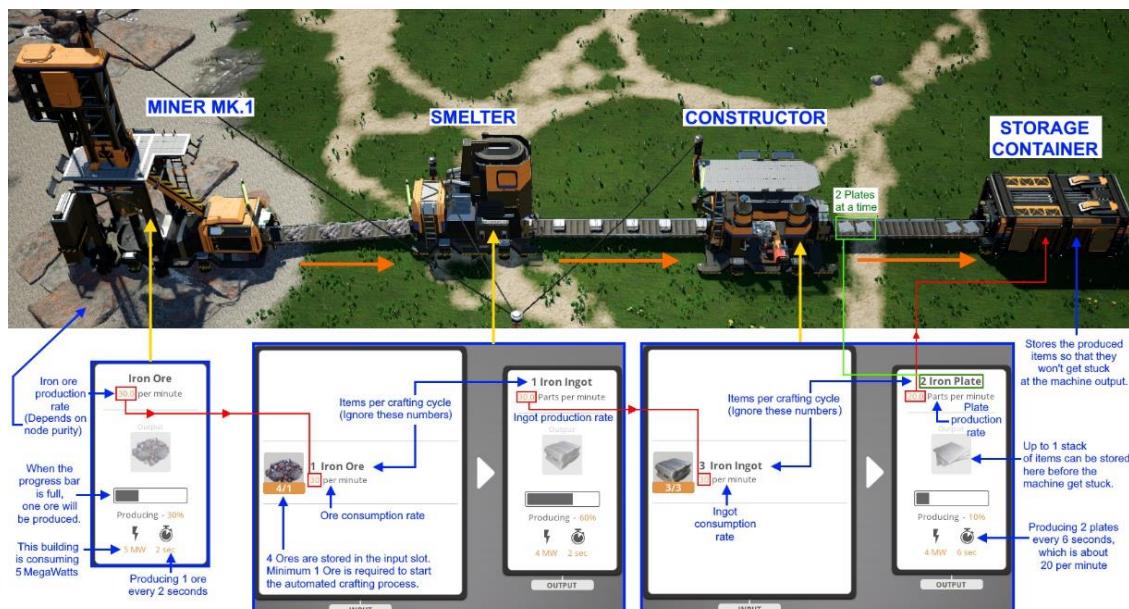


### 3 RESULTS

Satisfactory is a factory-building and automation simulation game developed by Coffee Stain Studios. Set in a science fiction universe, players assume the role of pioneers deployed by FICSIT Inc. to exploit natural resources on an alien planet. The primary objective is to automate increasingly complex production chains.

Initially released as early access in 2019 and officially launched in 2024, Satisfactory immerses players in the design, construction, and optimization of industrial systems. Players progress from manual collection of resources to fully automated production lines, a progression that mirrors real-world manufacturing development (Figure 4).

Figure 4 – Industrial automation in Satisfactory.



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One of the main goals is to produce advanced components for the Project Assembly, a fictional global initiative aimed at "saving Earth" from crises such as pollution, disease, and resource scarcity. Components are launched via a Space Elevator, depicted with three articulated robotic arms at 120° intervals (Figure 5).

Figure 5 – Space Elevator.



Players employ various machines and systems, offering rich analogies to real-world mechanical elements.

### 3.1 Machinery and mechanical correlations in gameplay

As students progressed through the virtual environment, they were encouraged to interpret the machinery encountered in the game not merely as visual elements, but as systems embedded with real-world engineering principles. The following machinery types are presented in the approximate order in which they are unlocked in the game, with some pedagogically motivated exceptions.

Constructors are basic machines with 1:1 production ratios, such as converting iron ingots into plates. Their animations involve robotic arms and hydraulic presses, ideal for discussions on interference fits, press fits, and fatigue under cyclic loads (Figure 6).

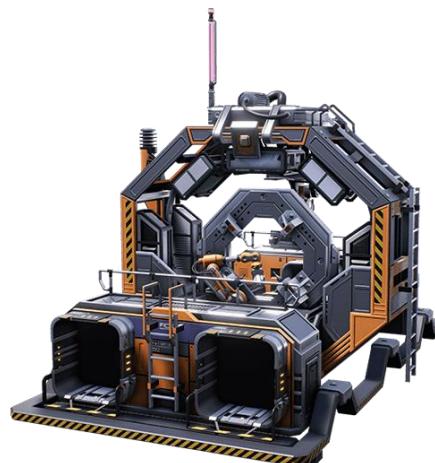
Figure 6 – Constructor unit.



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Assemblers combine 2 inputs into 1 output, such as manufacturing rotors. Their structure exemplifies torque transmission, alignment precision, and load paths (Figure 7).

Figure 7 – Assembler.



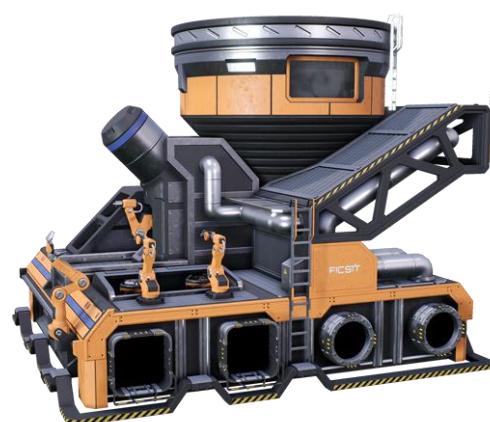
Manufacturers handle 3:1 or 4:1 production ratios, producing advanced electronics like computers and turbo motors. Robotic arms perform welding, cutting, quenching, and cooling, offering cases for multiaxial fatigue and shaft–tool coupling analysis (Figure 8).

Figure 8 – Manufacturer with dynamic robotic operations for complex production tasks.



Blenders mix fluids and solids to produce advanced materials such as turbo fuel or cooling systems. They illustrate rotational shafts under torsional load and fit design to prevent slip and shear (Figure 9).

Figure 9 – Blender system for fluid-solid mixture and mechanical shaft connection analysis.



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Miners extract ores like iron and coal. Their rotating shafts under axial and torsional loading are examples for interference fit joints and load-bearing couplings (Figure 10).

Figure 10 – Miner.



Coal Generators provide electricity by burning coal and boiling water. Mechanically, they exemplify shaft power transmission and shaft fatigue under cyclic loads (Figure 11).

Figure 11 – Coal Generator shaft-driven turbine systems.



Oil Extractors gather crude oil. Their valve assemblies and flange connections are analogous to lead screws and bolted joint fatigue (Figure 12).

Figure 12 – Oil Extractor.



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### 3.2 Vehicles

The Explorer is an off-road vehicle with high mobility. Its suspension system offers excellent examples for fatigue in springs and dynamic damping systems (Figure 13).

Figure 13 – Explorer off-road vehicle.



Trains transport both solids and fluids over long distances. They illustrate wheel-rail interaction, bending stresses, and fatigue in articulated couplings. In Satisfactory, trains are more permissive than real-world standards but still provide modeling analogies (Figure 14).

Figure 14 – Train system illustrating coupling fatigue.



### 3.3 Structural systems and connections

Tall lattice towers suspend electrical cables across the terrain. Bolted joints at the base are useful for preload analysis and bolt fatigue studies (Figure 15).

Figure 15 – Power transmission tower.



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Pipelines transport fluids through flanged connections. Cross-junctions allow multiple pipelines to merge or diverge, providing practical cases for multi-bolt flange design (Figure 16).

Figure 16 – Pipeline system with bolted flanged joints and fluid distribution.



In Satisfactory, there are only cross-junctions (not T-junctions), but unused exits are sealed automatically, allowing analogous functionality.

Radar towers reveal unexplored regions of the map. Structurally, they serve as analogues to telecommunication masts subjected to wind-induced fatigue (Figure 17).

Figure 17 – Radar tower structure under simulated environmental loading conditions.



### 3.4 Wearable mechanisms and mobility enhancements

In the advanced stages of gameplay, players gain access to wearable devices that enhance physical mobility and survivability. Among them, the Performance Leg Prosthesis is a modular exoskeletal attachment fitted to the character's legs, enabling faster running speed, higher jumping capability, and reduced fall damage. Although it functions as a passive gameplay enhancer, its implied mechanical architecture suggests a system of hinged linkages, actuated joints, and structural supports, bearing resemblance to powered lower-limb exoskeletons studied in biomechatronic and robotics.

While the game does not provide detailed internal views or animations of this equipment, owing to third-person view limitations, it nonetheless evokes meaningful engineering concepts.

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Students associated the repeated dynamic stresses involved in walking, jumping, and landing as analogous to fatigue loading conditions in prosthetic or exoskeletal applications. In particular, the joint regions, where axial and bending loads are transferred, could serve as basis for exercises on cyclic stress analysis, stress concentration factors, and design against fatigue failure.

Furthermore, the mechanical connections between segments of the exoskeleton could be explored within the scope of form fit joints, interference fits, and shaft-hub couplings. While no specific application was identified for course exercises, the conceptual alignment remains strong, especially as an interdisciplinary gateway to discussions that combine mechanical integrity, human-machine interaction, and ergonomic constraints (Figure 18).

Figure 18 – Blade Runners (Performance Leg Prosthesis) for mechanical load distribution analysis.



#### 4 CONCLUSIONS

This study demonstrated the pedagogical potential of Satisfactory as an auxiliary tool in the teaching of Machine Design. By immersing students in a dynamic virtual environment filled with mechanical systems, linkages, and production flows, the game allowed for meaningful correlations with real-world engineering components and concepts covered in the course. The qualitative feedback collected through interviews revealed that basic gameplay proficiency is typically acquired within a few hours. However, deeper engagement and decision-making, such as evaluating system efficiency or resource allocation, emerge only as students begin to reflect on the broader implications of their choices. This characteristic aligns well with the learning objectives of design education, where exploration, trade-offs, and optimization are central themes.

The collaborative multiplayer mode proved particularly effective in fostering division of tasks, coordination, and critical debate around system architecture. Students highlighted that shared goals and distributed responsibilities led to more efficient factory development and enriched the engineering reasoning process.

Overall, the integration of immersive, game-based platforms like Satisfactory into engineering education may enhance student motivation and offer a complementary approach to traditional analytical instruction, especially in reinforcing concepts such as fatigue, interference fits, transmission systems, and mechanical assemblies.

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