EVOLUX: A Gamified Model for Sustainable Process Innovation in the Era of Industry 5.0

Lucas de Freitas Gomes[1]*, Carlos Cesar Ribeiro Santos[1], Herman Augusto Lepikson[1]
[1]*SENAI CIMATEC University, Salvador, Bahia, Brazil*

The growing complexity of production environments highlights the limitations of isolated process improvement approaches, such as Lean, Six Sigma, or Simulation. This article introduces EVOLUX, a gamified model for process innovation that integrates established methodologies with governance mechanisms (OKRs) and emerging technologies (AI, blockchain, and digital twins). The proposal seeks to overcome existing fragmentation by aligning sustainable productivity, human engagement, and the principles of Industry 5.0. Based on a systematic review and critical analysis of the literature, theoretical and practical gaps are evidenced, which justify the need for an integrative framework. The expected results include greater operational predictability, scalability of innovation practices, and strengthening of teams' intrinsic motivation. Thus, EVOLUX is positioned as an unprecedented and relevant contribution for organizations aiming to combine competitiveness, sustainability, and human focus in their transformation processes.
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The pursuit of sustainable productivity and continuous innovation in industrial processes takes center stage in the era of Industry 5.0. Unlike Industry 4.0, characterized by its technological focus, Industry 5.0 emphasizes the integration of production efficiency, sustainability, and the appreciation of the human factor [1,2]. This new paradigm challenges organizations to overcome fragmented approaches and to articulate, within a single model, the technical, digital, and human dimensions of innovation.

In the Brazilian context, industrial labor productivity has grown at a slower pace compared to advanced economies, representing a structural barrier to competitiveness [3]. Although consolidated methodologies such as Lean Six Sigma, discrete-event simulation (DES), and agile frameworks have been widely applied, the literature shows that their isolated adoption limits the predictability of gains and the scalability of solutions [4]. At the same time, structured gamification has emerged as an alternative to foster motivation and collaboration in teams, but recent criticism points to risks when it is reduced to points, rankings, and extrinsic rewards, such as the weakening of intrinsic motivation, the tokenization of human effort, and team overload [5,6].

This combination of advances and gaps indicates the need for integrative frameworks. Models such as GLUX (Gamified Lean UX) exemplify the potential of combining agile practices with game elements, but their application remains restricted to the software domain [7]. There is, therefore, no methodological proposal that consolidates, on an industrial scale, the integration of gamification, emerging digital technologies, and continuous improvement methods with structured mechanisms for measuring both human and operational impact. This is the still underexplored space that grounds the present research.

This article proposes a gamified architecture designed to guide process innovation projects in industrial environments with a simultaneous focus on human engagement and sustainable productivity, called EVOLUX. Unlike existing frameworks, this architecture organizes the innovation journey into gamified macro-stages that integrate Lean Six Sigma, computational simulation, digital twins, adaptive artificial intelligence, blockchain, and OKR-based governance. It is important to

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Address for correspondence: Lucas de Freitas Gomes. Av. Eng. Gentil Tavares, 1166 - Getúlio Vargas, Aracaju - SE, Zipcode: 49055-260. E-mail: lucasfreitasgom@gmail.com.

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emphasize that EVOLUX is proposed here as a conceptual architecture not yet applied, whose objective is to fill methodological gaps identified in the literature and to provide a replicable and validatable basis for future empirical studies and applications.

Theoretical Framework and Foundations of the EVOLUX Model

The construction of a methodological architecture for process innovation with a focus on sustainable productivity requires a critical analysis of the approaches used in industrial environments. This section presents the foundations that support EVOLUX, highlighting contributions, limitations, and gaps of existing models in order to demonstrate the originality of the proposal.

Agile Methods and Organizational Sustainability

Agile methods such as Scrum, Kanban, and Lean Startup have become widely recognized for their ability to accelerate learning cycles, reduce implementation risks, and promote incremental value delivery [8]. However, their transposition to industrial contexts faces obstacles related to rigid hierarchical structures, cultural barriers, and the lack of metrics that demonstrate proven gains in productivity and sustainability [9].

Emerging models such as GLUX (Gamified Lean UX) indicate that the combination of agile practices and gamification can enhance engagement and collaboration [7]. Nevertheless, their application remains restricted to software development and does not extend to complex industrial processes. This limitation reinforces the need for a framework that unites agile flexibility, human engagement, and robust metrics in production environments.

In the context of Industry 5.0, organizational agility cannot be limited to rapid deliveries; it must be associated with sustainability, human centrality, and systemic resilience [10,11]. EVOLUX advances in this direction by incorporating agile practices into gamified macro-stages, supported by digital governance mechanisms and metrics that balance economic, environmental, and social outcomes.

Gamification as a Driver of Productive Engagement

Gamification, defined as the use of game elements in non-game contexts, has become consolidated as a strategy to foster motivation and collaboration [12]. Empirical evidence points to consistent benefits: Dolly and colleagues [13] reported performance increases in gamified assembly tasks; Capponi and colleagues [14] highlighted positive effects in human-robot collaboration scenarios.

However, recent criticism warns of the risks of superficial application. Krath and colleagues [5] emphasize that gamification based solely on points, badges, and leaderboards (PBL) does not sustain intrinsic motivation, potentially generating ephemeral engagement. Leite and colleagues [15] reinforce that the uncritical use of extrinsic mechanics can result in overload, toxic competition, and burnout.

To avoid such pitfalls, EVOLUX adopts the Octalysis Framework [16] as a reference, prioritizing deeper motivational dimensions such as purpose, belonging, creativity, and curiosity, which are directly connected to Self- Determination Theory [17]. Thus, gamification in EVOLUX is not limited to superficial rewards but is structured as a methodological core capable of sustaining continuous and meaningful engagement.

Emerging Technologies and Continuous Improvement

Industry 4.0 introduced technologies such as artificial intelligence (AI), blockchain, digital twins, and discrete-event simulation (DES), expanding the capacity to forecast scenarios and validate solutions. However, recent studies show that their adoption is not exempt from limitations. Awasthy and colleagues [18] highlight the energy and implementation costs of blockchain; AI may reproduce biases stemming from data quality; and DES strongly depends on the calibration of models to generate reliable results [19,20].

Despite these constraints, the integration of Lean Six Sigma (LSS) and DES has shown promising results. Goienetxea and colleagues [4] emphasized the potential of this combination but noted the absence of replicable and standardized frameworks. Recent cases confirm significant gains: Obradović and colleagues [9] documented increased productivity and cost reduction in a national industry, while Van Erp and colleagues [10] reported positive environmental impacts in logistics chains.

EVOLUX incorporates these technologies into gamified macro-stages, using DES and digital twins to validate improvement hypotheses before execution, adaptive AI for continuous adjustments, and blockchain for traceability. In this way, it combines technical robustness with human engagement, proposing a replicable path for process innovation.

<u>Hybrid Frameworks and Innovation Governance</u>

The increasing complexity of industrial environments has driven the use of hybrid frameworks, which combine different methodologies to expand innovation and execution capabilities. Design Thinking (DT) contributes to collaborative and human-centered ideation but lacks mechanisms for scalability [21]. Theory of Constraints (TOC) assists in identifying critical bottlenecks but tends to restrict systemic vision [22]. Meanwhile, Objectives and Key Results (OKRs) have proven useful for strategic alignment, although many organizations face difficulties in institutionalization (Rompho, 2024).

EVOLUX proposes the structured integration of these models: Design Thinking in the ideation phase, TOC for constraint analysis, and OKRs to connect process innovation with organizational goals. This arrangement strengthens innovation governance and increases predictability of results.

<u>Critical Synthesis and Positioning of EVOLUX</u>

The literature review shows that, although each approach contributes in specific ways, fragmentation still prevails: agile methodologies focus on flexibility, gamification often lacks motivational depth, emerging technologies face practical limitations, and hybrid frameworks do not consolidate integrated governance.

In this context, EVOLUX is not presented as a tested solution but as a conceptual methodological architecture. Its proposal is to fill identified gaps, such as the absence of replicable frameworks, lack of causal integration between human engagement and sustainable productivity, and the absence of robust measurement protocols in process innovation.

The model, therefore, offers a structured foundation for applied research and future empirical validations. As such, it positions itself as an original contribution to Industry 5.0, articulating resilience, sustainability, and human focus within a process innovation ecosystem.

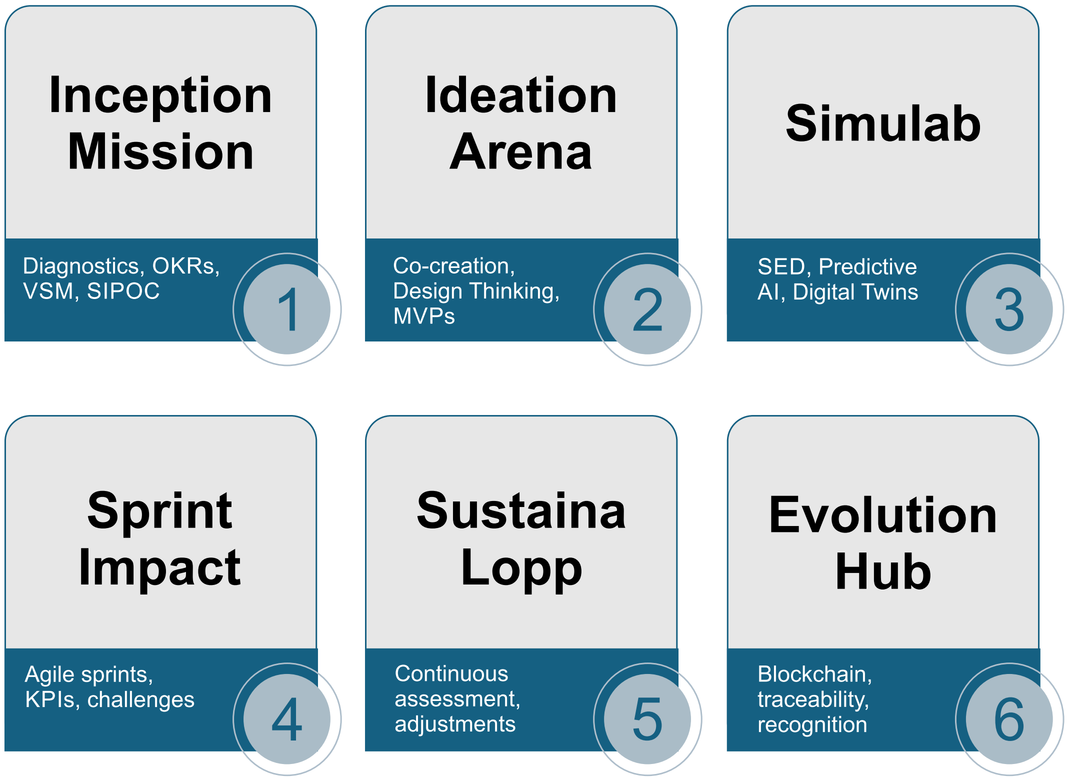
EVOLUX Method: Architecture and Macro-Stages

The model proposed here is organized into six evolutionary macro-stages that structure the cycle of industrial process innovation. Each macro-stage combines established tools, emerging technologies, and gamification mechanics designed to sustain motivation, collaboration, and objective measurement of results (Figure 1).

<u>Inception Mission – Diagnosis and Goal Setting</u>

The first phase of EVOLUX is dedicated to identifying bottlenecks and opportunities for innovation. It employs SIPOC, Value Stream Mapping (VSM), and Objectives and Key Results (OKRs) to map processes and align strategic objectives. Gamification occurs through rewards for accurate diagnosis, encouraging rigorous data collection and clarity in goal definition.

Figure 1. Steps of EVOLUX Method.



Ideation Arena – Co-Creation of Solutions

This phase promotes collaborative idea generation using Design Thinking and TRIZ, supported by generative AI to broaden creative repertoires. Teams earn points based on the originality, feasibility, and impact of their proposals, fostering engagement and ownership. The goal is to align creativity with practical applicability, overcoming the limitation of architectures focused solely on ideation.

Simulab – Computational Validation

Here, proposals are transformed into digital prototypes, validated through discrete-event simulation (DES) and digital twins. Metrics such as Return on Investment (ROI), cycle time, production capacity, and environmental impact are analyzed in simulated scenarios before real implementation. Gamification takes the form of performance challenges, where teams compete to propose more efficient and sustainable solutions.

Sprint Impact – Agile Implementation

This phase conducts the application of solutions in short sprints, with KPIs monitored through digital dashboards. Blockchain ensures traceability and integrity of records. Gamification manifests itself through "Impact Challenges," which reward efficiency, goal achievement, and innovation. In addition to motivating teams, this stage strengthens governance and organizational transparency.

Sustaina Loop – Continuous Adjustments

This is the phase of monitoring and incremental adjustments, supported by adaptive AI that suggests improvements in real time. Gamification is incorporated into innovation leagues, with collective recognition for replicable sustainable practices. This continuous cycle ensures that improvements are not limited to punctual gains but become consolidated as part of organizational culture.

Evolution Hub – Knowledge Management and Scalability

The final macro-stage is responsible for consolidating practices and results into digital repositories and gamified learning pathways. Blockchain guarantees innovation traceability, and internal certifications recognize teams for collective learning. This stage reinforces the evolutionary character of EVOLUX, promoting replicability and expansion across multiple sectors.

Future Validation Protocol

Although EVOLUX has not yet been empirically applied, its architecture foresees a scientific validation protocol across four axes:

a) **Maturity Assessment** – prior diagnosis of digital and governance readiness, guiding modular adoption of the model, from simplified stages (diagnosis, ideation, simulation) to the complete cycle;
b) **Human Engagement** – measurement based on Self-Determination Theory (Deci & Ryan, 1985) and the Octalysis Framework (Chou, 2019), using psychometric scales of autonomy, purpose, and motivation;
c) **Sustainable Productivity** – Lean Six Sigma and sustainability indicators (OEE, lead time, sigma level, ROI, emissions, waste);
d) **Statistical Method** – application of Difference-in-Differences (DiD) and mixed models to isolate the effects of EVOLUX in control and intervention groups.

This protocol ensures that results are not only perceived but also supported by robust empirical evidence.

Expected Results and Contributions of EVOLUX

EVOLUX distinguishes itself by integrating, within a single architecture, the technical, human, and digital dimensions of organizational innovation. It is a conceptual proposal not yet empirically validated but structured to address recognized gaps in the literature and to guide future applications. Its contributions are distributed across three fronts: practical, theoretical, and multisectoral applicability.

Practical Contributions

a) **Operational Predictability** – the integration of predictive simulation and digital twins enables decision-making based on validated scenarios, reducing implementation risks and increasing the reliability of improvements.
b) **Sustainable Human Engagement** – by adopting intrinsic motivational principles (Octalysis, SDT), EVOLUX seeks to mitigate the risks of superficial gamification and strengthen continuous motivation, fostering collaboration and overcoming cultural resistance in change processes.
c) **Scalability and Traceability** – by adopting intrinsic motivational principles (Octalysis, SDT), EVOLUX seeks to mitigate the risks of superficial gamification and strengthen continuous motivation, fostering collaboration and overcoming cultural resistance in change processes.

Theoretical Contributions

a) **Original Integration** – structured connection between gamification, Lean Six Sigma, computational simulation, adaptive artificial intelligence, and governance mechanisms (OKRs, TOC, DT), articulated within a replicable architecture.
b) **Response to Industry 5.0 demands** – aligning process innovation with three central pillars – human centricity, systemic resilience, and environmental sustainability [10,11].
c) **Overcoming Conceptual fragmentation** – while agile methodologies, gamification frameworks, and continuous improvement approaches have advanced in isolated domains, EVOLUX proposes an architecture that

connects technical and human dimensions in a causal and validatable manner.

Multisectoral Applicability

EVOLUX was designed to adapt to different levels of digital maturity: (a) low maturity: traditional sectors, such as textiles, may adopt simplified versions focused on diagnosis, ideation, and simulation; (b) medium maturity: discrete manufacturing can apply the complete architecture, supported by AI and OKR governance; (c) high maturity: R&D environments and technology-intensive industries may explore the full potential of the model, with advanced integration of blockchain, digital twins, and adaptive artificial intelligence. The prior assessment of maturity is a fundamental part of the methodology, functioning as a calibration stage to define which EVOLUX macro-stages can be implemented immediately and which should be incorporated gradually. In this way, the model avoids generic prescriptions and adapts to the real conditions of each organization, promoting greater predictability and suitability in the adoption process.

Conclusion

EVOLUX was conceived as a gamified architecture to guide industrial process innovation projects, integrating human, technological, and operational dimensions into a single methodological ecosystem. Structured into six evolutionary macro-stages, the model organizes the journey from diagnosing bottlenecks to knowledge management, promoting continuous innovation based on established methodologies (Lean Six Sigma, agile frameworks) and emerging technologies (artificial intelligence, computational simulation, digital twins, and blockchain). This configuration differentiates itself by aligning sustainable productivity with the construction of an organizational culture that is resilient and focused on human engagement.

One of the central aspects of the model is the emphasis on intrinsic engagement, supported by Self-Determination Theory and the Octalysis Framework, ensuring that innovation is not limited to technical gains but strengthens motivation, collaboration, and organizational resilience. In parallel, the use of operational performance metrics — such as OEE, lead time, and sigma level — ensures that the proposal goes beyond the conceptual field and can be empirically validated in terms of productive efficiency and environmental sustainability.

Methodological flexibility represents another relevant contribution of EVOLUX. The digital and governance maturity assessment, conducted prior to application, allows for calibration of adoption according to the technological and cultural readiness of each organization. This arrangement prevents generic prescriptions and makes the model scalable, adaptable, and applicable across multiple sectors, from traditional industries to high-tech environments.

Although still presented as a conceptual architecture, EVOLUX establishes a solid foundation for future validations. The proposed testing protocol combines human and productive metrics with advanced statistical methods, expanding the potential for generalization and replication across different organizational contexts. Future steps include pilot applications, the consolidation of an EVOLUX readiness index, and the deepening of human impact metrics, such as well-being, autonomy, and resilience.

In summary, the model represents an original contribution by proposing a replicable and adaptable methodology to align innovation, human engagement, and sustainable productivity, in line with the principles of Industry 5.0.

References

1. Van Erp, J., van der Helm, A., Hilletofth, P., & Jafari, H. Outlook on human-centric manufacturing towards Industry 5.0. Journal of Manufacturing Systems, 70, 385–400, 2024.
2. Lu, Y., Xu, X., & Wang, L. Smart manufacturing process and system automation – A critical review of

Industry 4.0 and Industry 5.0. Journal of Manufacturing Systems, 65, 421–439, 2022.
3. Confederação Nacional da Indústria (CNI). Industrial Productivity. Brasília: CNI, 2024 [cited 2025-09-15]. Available at: https: // www.portaldaindustria.com.br/estatisticas/produtividade-na-industria/.
4. Goienetxea Uriarte, A., Ng, A. H. C., & Urenda Moris, M. Bringing together Lean and simulation: a comprehensive review. International Journal of Production Research, 58(1), 87–117, 2020.
5. Krath, J., Schürmann, L., & von Korflesch, H. Revealing the theoretical basis of gamification: a systematic review and analysis of theory use in gamification literature. Computers in Human Behavior, 125, 106963, 2021.
6. Kim, T. W., & Werbach, K. More than just a game: ethical issues in gamification. Ethics and Information Technology, 18(2), 157–173, 2016.
7. Alhammad, M. M., & Moreno, A. M. GLUX: [full title truncated]. Lecture Notes in Computer Science, 12793, 2021.
8. Rigby, D. K., Sutherland, J., & Noble, A. Agile at Scale: how to go from a few teams to hundreds. Harvard Business Review, 96(3), 88–96, 2018.
9. Obradović, V., Todorović, M., & Bushuyev, S. Sustainability and Agility in Project Management: Contradictory or Complementary? Sustainability, 12(5), 1–15, 2020.
10. Van Erp, T., Carvalho, N. G. P., Gerolamo, M. C., Gonçalves, R., Rytter, N. G. M., & Gladysz, B. Industry 5.0: A new strategy framework for sustainability management and beyond. Journal of Cleaner Production, 461, 142271, 2024.
11. Lu, Y., Zheng, H., Chand, S., Xia, W., Liu, Z., Xu, X., Wang, L., Qin, Z., & Bao, J. Outlook on human-centric manufacturing towards Industry 5.0. Journal of Manufacturing Systems, 62, 612–627, 2022.
12. Deterding, S., Dixon, D., Khaled, R., & Nacke, L. From game design elements to gamefulness: defining gamification. In Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments (MindTrek '11), Tampere, Finland, pp. 9–15, 2011. ACM.
13. Dolly, R., et al. Gamification effects on assembly tasks: productivity gains and temporal load. Robotics and Computer-Integrated Manufacturing, 86, 102654, 2024.
14. Capponi, A., et al. Gamification in human -robot collaboration: preliminary insights and results. International Journal of Advanced Manufacturing Technology, 129, 4567–4582, 2025.
15. Leite, R. M. C., Alves, L. R. G., Cardoso, L. S. P., & Neto, H. M. M. How Has Gamification in the Production Sector Been Developed in the Manufacturing and Construction Workplaces? Buildings, 13(2614), 1–20, 2023.
16. Chou, Y.-K. Actionable Gamification. Octalysis Media, 2019.
17. Deci, E. L., & Ryan, R. M. Intrinsic Motivation and Self-Determination in Human Behavior. New York: Plenum Press, 1985.
18. Awasthy, P., Haldar, T., & Ghosh, D. Blockchain enabled traceability — An analysis of pricing and traceability effort decisions in supply chains. European Journal of Operational Research, 321(3), 760–774, 2025.
19. Law, A. M. Simulation Modeling and Analysis (5th ed.). New York: McGraw-Hill, 2014. ISBN: 978-0073401324.
20. Kelton, W. D., Sadowski, R. P., & Zupick, N.
B. Simulation with Arena (6th ed.). New York: McGraw-Hill, 2014. ISBN: 978-0073401317.
21. Johansson-Sköldberg, U., Woodilla, J., & Çetinkaya, M. Design Thinking: Past, Present and Possible Futures. Creativity and Innovation Management, 22(2), 121–146, 2013.
22. Mabin, V. J., & Balderstone, S. J. The World of the Theory of Constraints: A Review of the International Literature. Boca Raton: CRC Press, 2003. ISBN: 9781420025569.