

Research Article

# Towards the Gamification of Systems Engineering Practice

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## Abstract

Our goal is to integrate gamification into real-world systems engineering practice to enhance the effectiveness and engagement of systems engineers working in team environments. A central challenge in this context is that directly overlaying explicit gamification elements—such as points, badges, or leaderboards—onto professional workflows is often impractical and may disrupt established engineering processes. Therefore, gamification strategies must be grounded in data that can already be collected from the existing engineering environment. These strategies should provide actionable behavior cues that align with both individual performance metrics and broader team objectives, ensuring consistency with established engineering goals. In this approach, the “game” is not artificially created but inherently exists within the systems engineering process itself. The role of gamification researchers is to make this implicit game visible—by clarifying the process, highlighting cause-effect relationships, and presenting progress in a form that is intuitive and motivating for all stakeholders. This requires accurately modeling the complexity of modern systems engineering, monitoring activities in real time, and translating data into clear, causal performance feedback. By embedding gamification into the way results are visualized and understood, we aim to drive positive behavioral change. This paper details our methodology, reports current findings, and outlines future research directions.

## Keywords

System Engineering, Automatic Appraisal, Gamification

## 1. A Platform Approach to Systems Engineering Process Monitoring

How does one approach the gamification of the systems engineering process in practice? We base our approach on systems engineering intelligence, which seeks to measure the performance of engineering teams in delivering complex system designs. As teams collaborate using a variety of engineering tools (both technical and social), detailed data regarding the engineering process is generated. These measures range from metrics capturing the quality and progress of system design components to those recording the pace of individual and team work, collaboration in problem-solving, and other aspects of

the complex engineering process. By combining these data with longitudinal measures of changing system quality, we aim to explain and link engineering practices to outcomes in terms of individual and team performance [1].

However, the volume of data to be considered is vast, and the computational analysis required is resource-intensive. A critical challenge in delivering this approach is efficiently processing these datasets to achieve the near real-time response needed to support engineering teams during their daily tasks. Without this, gamification is nearly impossible. Over

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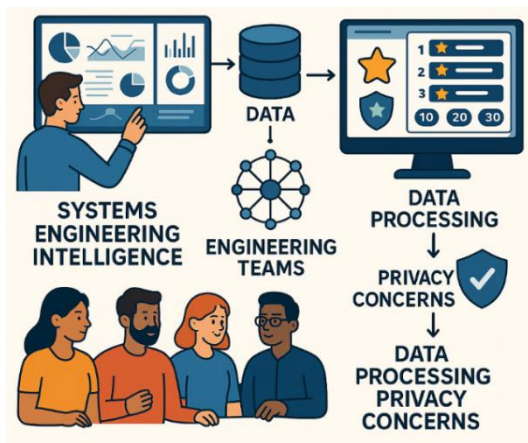


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the past few years, we have developed a scalable methodology and platform capable of gathering and processing large amounts of data. Our systems currently profile tens of thousands of engineering teams and their project activities, yielding fine-grained quantitative and social network data about all aspects of the systems engineering process. This is vital because, in practice, most engineering metrics have limited value unless compared to statistically significant data from other engineering teams [2].

Moreover, concerns regarding the unauthorized use and misuse of fine-grained measurements arise when monitoring moves from coarse-grained data (e.g., task completion) to fine-grained data (e.g., specific interactions and activities). As noted by Provost and Fawcett, "fine-grained data that provides the most compelling analytics about development is also the largest obstacle to industrial adoption" [3]. Our collaboration with engineering teams suggests that, in practice, an equally significant concern is the accuracy of analysis performed using such datasets. We believe gamification offers a practical model that can address data sovereignty concerns while enabling the sharing of meaningful assessment data among stakeholders [4].

To effectively implement gamification in systems engineering, it's essential to integrate real-time performance evaluation mechanisms. Studies have shown that real-time feedback significantly enhances employee engagement, with 72% of employees feeling more motivated when they receive immediate feedback [14]. By incorporating gamified elements such as leaderboards, badges, and point systems into performance evaluation software, organizations can foster a culture of continuous improvement and collaboration [15].



**Figure 1.** Gamification Platform.

Furthermore, integrating gamification into performance systems has been linked to increased motivation and retention. For instance, Deloitte transformed its annual review process into a dynamic, real-time feedback system called "Deloitte University," resulting in a 20% increase in performance metrics within the first year [16]. Similarly, Cisco

implemented a digital platform with gamified elements, leading to a 30% improvement in the speed of performance assessments [17].

In conclusion, the integration of gamification into systems engineering processes, supported by real-time data analytics, can lead to enhanced performance, increased engagement, and improved collaboration among engineering teams. By addressing challenges related to data processing and privacy concerns, organizations can harness the full potential of gamification to drive success in complex system designs.

## 2. Automating Systems Engineering Appraisal

The key next step in our research agenda is to develop efficient methods for the real-time social analysis and gamification of these data sets in order to deliver actionable insights. We take the mentor relationship between engineer and line manager as the model by which a gamification strategy based on performance appraisal can be built. The game dynamic is to demonstrate how engineer actions contribute to the team performance, seeking to inculcate a matching conceptual model of this relationship in the mind of the supervised. In practice this amounts to the development of an expert system capable of software engineering performance appraisal.

Our approach to this is to consider system engineering as a social network process that generates complex system as the primary artifact. This makes it possible to apply a variety of behavioral and social analysis frameworks such as Pentland's social physics model of influence, social learning, and peer pressure between individuals to understand the development process [5]. Moreover, it allows for the development of an expert systems view of system engineering practice, encoded as evidence based argumentation schemes, that can be used to differentiate the observed behavior of engineering teams, and thereby trace and attribute the behavioral impact on process efficiency and output quality. By combining an analysis of group dynamics with a fine-grained analysis of the individual's behavior and performance, qualitative questions regarding system engineering practice can be addressed in an automated way, grounded in empirical data.

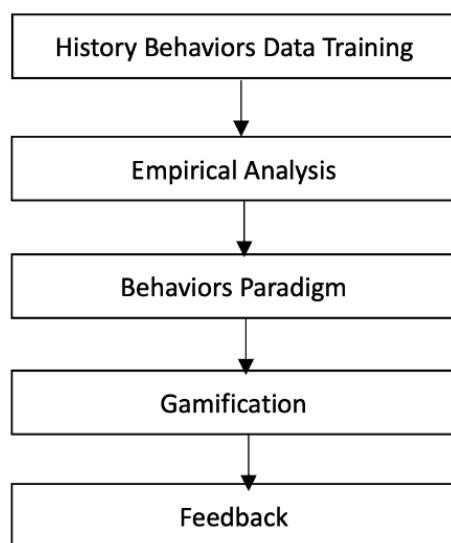
Our methodology is broadly inferential, leading to the development of knowledge representations that are executable over the digital footprint of system engineering activity. We begin by systematically and comprehensively gathering all relevant field data regarding the social engineering processes under study, and then analyses the patterns within these data in ex post facto studies. Relevant data sets include longitudinal measurement of source code change and quality; repository meta-data from toolsets such as git and subversion; measures of social network activity within development ecosystem toolsets such as bug tracking systems, chatrooms, private messaging in tools, email and so forth; data derived from the instrumentation of system development toolsets [6]; and sociometric data that

records the environmental and social context.

Informed both by these data sets and by a knowledge representation of system engineering process management, social computing and gamification, we seek to construct a set of models and frameworks that capture the range of relevant and plausible human judgement and reasoning regarding observable system engineering processes and enhance efficiency and performance of system engineering. Broadly, the goal is to capture the reasoning that a skilled system development manager might present, if he or she were in a position to consider the totality of performance evidence. These models are abstract and necessarily non-monotonic [7] in that they capture a network of interacting facts and arguments structured as conditional statements in predicate logic regarding qualitative concepts in the system engineering domain, abstracted from any particular engineering scenario or evidence set.

These abstract models are then developed further to instrument them, by a process of context specific argument selection, elaboration and probabilistic grounding in measurable data sets derived from specific engineering scenarios. This work is necessarily situated, and to this end we are engaged in a collaborative research strategy with real-world system engineering teams. In working with such teams, we have found strong and encouraging interest in the insights the approach can yield.

With an encoding of human judgment built, the resulting instrumented models can then be executed over data gathered, delivering a computational framework for comparative qualitative analysis over quantitative data. We believe that there are universal aspects to system engineering practice that can be better understood by consideration of their application and impact in the large, across a wide set of contexts. To this end, our goal is the incorporate particular insights developed in specific real world contexts into our platform so as to deliver a comparative analytics capability.



**Figure 2.** Automating Systems Engineering Appraisal.

### 3. Gamification of Performance in Systems Engineering

With the ability to appraise the performance of systems engineers in the context of team collaboration and system design, and grounded in real-world data linking behaviors to performance outcomes, we seek to demonstrate to engineers how specific actions impact overall system performance. This ability to correlate cause with effect provides the foundation for gamifying those aspects of the engineering process that are crucial for enhancing performance.

We do not believe a one-size-fits-all strategy for the gamification of systems engineering exists. However, we do believe that, based on systems engineering theory and practice, there are certain behaviors and practices that are more or less appropriate in specific engineering contexts. Our approach envisions a configurable method in which certain behavior sets can be selected for with appropriate rewards. For example, the behaviors of balancing system complexity and achieving functionality might conflict in certain circumstances, but effective gamification strategies can help engineers make better decisions within such trade-offs, maximizing overall team performance while adhering to constraints such as time or resources.

To operationalize this, we propose a modular gamification framework that allows for the customization of game elements—such as points, badges, leaderboards, and challenges—to align with specific team objectives and project requirements. This adaptability ensures that the gamification strategy remains relevant and effective across diverse engineering scenarios. For instance, in projects where innovation is paramount, the system can reward creative problem-solving and risk-taking behaviors, whereas in safety-critical systems, adherence to protocols and thorough testing may be incentivized.

Moreover, integrating real-time feedback mechanisms into the gamification framework is essential for reinforcing desired behaviors promptly. By providing immediate insights into how individual actions contribute to team goals, engineers can adjust their strategies dynamically, fostering a more responsive and agile development environment. This real-time feedback loop not only enhances individual performance but also promotes a culture of continuous improvement and learning within engineering teams.

In addition to individual incentives, incorporating collaborative game elements can strengthen team cohesion and collective performance. Features such as team-based challenges, shared milestones, and group rewards encourage collaboration and knowledge sharing among team members. This collective approach to gamification acknowledges the interdependent nature of systems engineering tasks and leverages social dynamics to drive performance.

Furthermore, the ethical considerations of gamification must be addressed to ensure that the system promotes positive behaviors without inducing undue stress or competition.

Transparent criteria for rewards, equitable opportunities for recognition, and mechanisms for feedback and adjustment are crucial for maintaining trust and motivation among participants. By prioritizing ethical design principles, the gamification framework can enhance engagement while safeguarding the well-being of engineering professionals.

In summary, our approach to gamifying performance in systems engineering is centered on a flexible, data-driven framework that aligns game mechanics with specific project goals and team dynamics. By integrating real-time feedback, promoting collaboration, and adhering to ethical design principles, we aim to create a gamification strategy that not only enhances individual and team performance but also contributes to the overall success of complex engineering projects.

## 4. Related Work

Gamification has been effectively utilized across various domains, including education, online communities, and business, to enhance user engagement and motivation. By incorporating game-like elements such as points, badges, and leaderboards, these sectors have witnessed improvements in user participation and satisfaction. Researchers have identified ten key gamification features that contribute to these positive outcomes [13]. Among these, the use of rewards stands out as a prevalent strategy to stimulate user motivation [8].

In the business sector, several gamification frameworks have been adopted to align with organizational goals and user needs. Notably, the 6D framework, the Mechanics-Dynamics-Aesthetics (MDA) framework, and the Octalysis framework have been instrumental in designing engaging experiences. The Octalysis framework, for instance, delves into eight core drives that influence human behavior, providing a comprehensive approach to gamification design [9]. Additionally, methodologies based on user-centered design (UCD) and model-driven architecture (MDA) approaches have been employed to ensure that gamification strategies are tailored to user preferences and system requirements [9].

In the realm of system engineering, a primary objective is to enhance system efficiency and developer productivity. Drawing inspiration from successful gamification applications in other fields, there is a growing interest in leveraging gamification to motivate developers and improve system engineering processes. However, previous research efforts in this area have often faced challenges due to a limited understanding of gamification design processes [10]. Moreover, there is a noticeable absence of a clear, standardized gamification framework specifically tailored for system engineering contexts.

Current gamification methods in system engineering predominantly draw upon cognitive principles such as Self-Determination Theory (SDT) [11], Flow Theory, and Group Flow Theory [12]. While these theories offer valuable

insights into human motivation and engagement, their application in software engineering gamification has often lacked depth and specificity. There is a disconnect between the theoretical underpinnings of these cognitive models and the practical implementation of gamification features and frameworks within system engineering environments.

To address these gaps, we propose synthesizing existing gamification design methods from systems engineering and developing a detailed methodology tailored for the engineering of gamified systems. This approach involves integrating established cognitive theories with practical design frameworks to create comprehensive models that effectively link gamification features with desired outcomes in software engineering. By doing so, we aim to establish a robust foundation for implementing gamification strategies that enhance developer motivation, foster collaboration, and ultimately improve software development processes.



Figure 3. Gamification Application.

## Abbreviations

|     |                               |
|-----|-------------------------------|
| MDA | Mechanics-Dynamics-Aesthetics |
| UCD | User-Centered Design          |
| SDT | Self-Determination Theory     |
| HS  | Shrinkage According Height    |
| DS  | Shrinkage According Diameter  |

## Author Contributions

Wei Ren is the sole author. The author read and approved the final manuscript.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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