

Use of Gamification as Implementation Approach for Software Process Improvement: Trends and Gaps

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Abstract: Studies carried out in the context of software process improvement (SPI) report problems and difficulties that organizations face to implement process models and standards, mainly related to the inability to overcome some critical factors. Thus, properly conducting SPI can facilitate the development of more efficient processes to overcome such difficulties, using gamification elements. Therefore, this paper aims to identify problems in the implementation phase of an SPI effort and use gamification as a tool to mitigate barriers during SPI implementation in a company that opted for an SPI program such as CMMI (Capability Maturity Model Integration) and / or MR-MPS-SW (Reference Model for Brazilian Software Process Improvement) and create the applicability guide using gamification in SPI that can be used by software organizations. The search string returned 499 (four hundred and ninety-nine) studies, of which 07 (seven) were selected according to the Systematic Literature Review presented in this paper.


1 INTRODUCTION


Public and/or private companies that develop software use methodologies, approaches and / or strategies for Software Process Improvement (SPI), otherwise, according to Montoni (2010), the absence or realization of these approaches without maturity are the main factors of failure of SPI.


For Montoni (2010), successful implementation of SPI initiatives essentially depends on strategies and approaches adopted to support the execution of such initiatives. Thus, the absence or lack of adequacy of these approaches is one of the most common reasons for the failure of improvement initiatives. In addition, Bayona (2012) states that other factors are also identified as causing failures in the conduct of these initiatives, such as organizational and technical management factors, lack of communication, motivation and top management support.

Companies aim to improve their software development processes to maximize performance related to cost, schedule, productivity, quality, customer satisfaction and return on investment (Goldenson and Gibson, 2003). To achieve this objective, they seek to implement national and / or international models, already consolidated, which define the requirements for the SPI, in addition to evaluating and certifying the company's level of maturity to the chosen model (Soares and Oliveira, 2020a).

Two models used in the SPI initiative can be highlighted, the Capability Maturity Model Integration - CMMI (CMMI Institute, 2018) and Brazilian Software Process Improvement - MPS.BR (SOFTEX, 2021). At the initial levels of these improvement programs, organizations adopt measurements that consist of collecting project execution data and comparing these with the planned values. While this is a sufficient approach, it is not

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suitable for organizations seeking high maturity, evaluating and evolving their processes.

For the development of this work, a Systematic Literature Review (SLR) was carried out. This research methodology allows, in a fair way, an evaluation and interpretation of the available literature, with the objective of answering one or several questions in a study area, in a systematic way and under the control of the researcher (Kitchenham et al., 2015).

In view of the above, this work presents a Systematic Literature Review with the objective of investigating which problems exist in the implementation phase of an improvement effort based on models as CMMI and / or MPS.BR and how the Gamification can help to reduce / remediate these difficulties.

The next sections of this work are organized as follows: Section 2 presents some concepts on the topic of this research, Section 3 details the study design, Section 4 brings the results, Section 5 presents the discussions, Section 6 addresses some threats to the validity of this work, Section 7 brings some related works and Section 8 closes this work by presenting the conclusions.

2 BACKGROUND

This section introduces concepts related to two topics treated in this paper: SPI and gamification.

Software Process Improvement is defined as a set of partially ordered steps intended to achieve an objective within the context of software development (Feiler and Humphrey, 1993). This concept allows framing and organizing different activities related to a software organization.

The SPI consists of a set of coherent policies, organizational structures, technologies, procedures and work products, necessary to conceive, develop, implement and maintain a software product (Fuggeta, 2000).

Software development is inserted in a very dynamic context, presenting a very fast pace (Wang and King, 2000). Therefore, developer companies define their software processes in order to increase product quality, strengthen their competitive position in the market (Komi-Sirvö, 2004) and meet customer requirements within the specified time and budget (Greenwood et al., 1996). However, human-centered processes can exhibit unexpected or unwanted performance and behaviors, so they need to be continually evaluated and improved (Fuggeta, 2000; Unterkalmsteiner et al., 2012).

This environment of continuous change and refinements motivates the creation of quality models and methods for SPI, a program of activities designed to improve the performance and maturity of the organization's processes (CMMI Institute, 2018). According to Hall et al. (2002), software organizations that implement SPI through the adoption of standards or models report significant benefits.

As a second topic discussed in this paper, Gamification can be defined as a practice that uses game elements and mechanics to spread teachings and even training to the participants of the practice (Mcgonical, 2011). As the current generation grew up in the contemporary age of gaming, this closeness and familiarity has positive aspects in learning.

The purpose of gamification is not to create an electronic game, but to use the same methods, techniques and thoughts used in virtual games for situations that occur in the real world. Thus, there is the emergence of gamification, which consists of the use of game elements out of context, with the purpose of mobilizing subjects to action, assisting in problem solving and promoting learning (Kapp, 2012).

For Kapp (2012), gamification can motivate individuals to action, assist in problem solving and promote learning. In the educational environment, the main challenge of gamification is to involve students within the gamified context of learning, so that they can master the material that is being taught to them.

3 STUDY DESIGN

This section presents the objectives of the work, the research questions and the method used.

3.1 Goal and Research Question

The present study aims to investigate what problems exist in the implementation phase of a model-based improvement effort based on the CMMI and / or MPS.BR models and how gamification can help to reduce / remediate these difficulties.

Thus, we propose the following research questions (RQ):

- RQ1: What gamification practices can help in SPI?
- RQ2: What are the problems and / or difficulties of a company in the implementation of SPI?
- RQ3: What types of approaches have been used to implement SPI in a company / organization?

3.2 Method

To achieve the objective of this study, a Systematic Literature Review (SLR) was carried out. RSL is a scientific research methodology that has been applied in the most diverse areas of knowledge. This methodology allows, in a fair way, an evaluation and interpretation of the available literature, with the objective of answering certain questions about an area of study. Thus, the evaluation is carried out systematically, under the control of the researcher (Kitchenham et al., 2015).

Planning for this SLR includes the following steps: planning, conducting and presenting (Kitchenham et al., 2015). Planning takes place through the definition of objectives, research sources, evaluation criteria of primary studies, quality criteria, extraction and analysis of data from primary studies, analysis of sources, planning of data analysis and search string.

Three researchers participated in the planning and execution of the work: a PhD student in graduate studies in Computer Science and two professors / researchers with a PhD in Software Engineering.

3.3 Search Strategy

The search occurred in an automated way through a string formed by a series of keywords and their respective synonyms. These keywords were defined based on the research questions, following the PICOC (Population, Intervention, Comparison, Outcomes and Context) structure suggested by Kitchenham and Charters (2007).

However, the objective of this research is to identify gamification practices to assist in SPI, applicable in the context of organizations (companies, institutions, centers and groups) that work on software projects (Population), in the form of process models, techniques, methodologies, and gamification practices (Outcomes).

In this way, the string was formulated with terms related to (i) population, (ii) intervention, (iii) comparison, (iv) outcome and (v) context. The terms used were:

- Population: Software organizations and software improvement projects,
- Intervention: Identify gamification practices that can help in SPI,
- Comparison: Approaches to traditional improvement models,
- Result: Process models, improvement methodology, techniques, methodologies, tools, standards, methods, techniques, guide and

gamification practices to solve/reduce problems in an SPI effort,

- Context: Software industry.

The search string (as can be seen in Table 1) was applied to the IEEEExplore and ACM DL databases, as they meet the aforementioned criteria, have an expressive base of articles / papers and a high degree of quality. The studies search method will be automatic, carried out through web search engines by keywords.

Table 1: Search String.

(Software organization) AND ((gamification OR game*) AND (software process improvement OR SPI OR (improvement AND (planning* OR implementation* OR evaluation*)))) AND (Process models OR quality models OR techniques OR methodologies OR tools)

3.4 Study Selection

In this stage of the work, inclusion (IC) and exclusion (EC) criteria were applied, in order to select only the relevant works that answered our research questions. The IC and EC are presented below.

- IC: Studies that present, primarily or secondarily, gamified practices or gamification applied to software process improvement,
- EC: Studies that are not written in English, studies not available for download openly or through the institutional IP of the researchers, studies such as workshop reports, posters, presentations, speaker keynotes, books, theses and dissertations.

Each of the studies underwent a selection process consisting of four steps: (i) three researchers read the titles and abstracts of all studies and applied the exclusion criteria, this step was defined as pre-selection, (ii) the same researchers discussed differences in the application of exclusion criteria to reach a consensus, (iii) the researchers read the title and abstract, and the full text if necessary, of the studies selected in the first step to apply the inclusion criteria, (iv) the researchers discussed differences in the application of exclusion criteria to reach a consensus. The process described resulted in 7 primary studies, available at <https://zenodo.org/record/6046131>.

3.5 Study Classification and Data Extraction

To collect the necessary data that answer the

research questions defined for this work, a researcher was responsible for reading the 7 selected studies.

Data analysis aims to classify the studies according to the proposed research questions. Therefore, the result of this SLR should map and classify studies regarding: what are the problems during the implementation of software process improvement and how to use gamification to solve and / or reduce problems and difficulties that organizations face during the implementation of SPI.

4 RESULTS

This section presents the results of SLR. Subsection 4.1 presents an overview of the results. Subsections 4.2, 4.3 and 4.4 describe the results for RQ1, RQ2 and RQ3, respectively. In these subsections, the primary studies will be referenced and identified by codes and are available at the URL presented in subsection 3.4.

4.1 Overview

This SLR searched for studies between the years 2011 and 2021. The search resulted in 499 studies, with 485 found in the ACM Digital Library and 14 in IEEEExplore. However, only 07 primary studies (after the inclusion and exclusion criteria) were selected among the 499, and are distributed between the years 2014 and 2021, as shown in Figure 1. Still based on Figure 1, we can see that there are few studies involving gamification with an approach to SPI, the trend is for a growth in the number of publications related to the subject of this work, given that many universities and companies needed to reduce their research activities due to the pandemic.

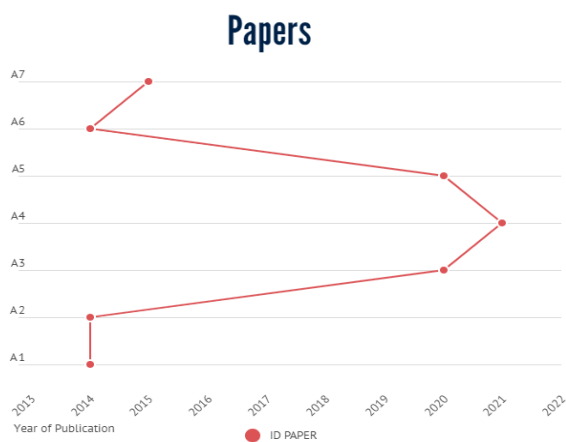


Figure 1: Distribution of studies by year.

The study [A1] presents an approach that uses game theory to facilitate the interaction between players in an SPI initiative, in a real environment. The study [A2] presents a teaching tool based on the principles of gamification to achieve the level of motivation required in teams involved in SPI. The study [A3] uses gamification as a systematic strategy in the teaching and learning of tests through an experiment with undergraduate students in Computer Science and the other with students graduated in Computer Technicians. The study [A4] identifies models and strategies for evaluating elements of gamification already reported in the literature in the context of software engineering. The study [A5] presents an experiment of a proposal to teach the software measurement process from gamification using game and serious game elements. The study [A6] proposes the use of gamification to increase the quality of user feedback, and consequently, improve the quality of the software. And, finally, the study [A7] makes a comparison of two work environments, with and without gamification; the gamified environment shows better performance and accuracy in its results.

4.2 Gamification Practices to Assist in SPI

This subsection presents results related to RQ1 (“What gamification practices can help in MPS?”).

In the selected studies it was not possible to identify the gamification elements to solve the identified problems. Only in Section 7 (Related Works) can the gamification elements be identified (Soares and Oliveira, 2021).

4.3 Problems and / or Difficulties of an Organization in Implementing SPI

This subsection gives an overview of the main problems and / or difficulties companies face in an MPS initiative. From the selected studies, it was possible to identify the problems in the SPI initiatives, as can be seen in Table 2.

4.4 Types of Approaches Have Been Used to Implement SPI in an Organization

This subsection presents the approaches used in an SPI initiative implementation.

From the selected studies, it was possible to identify that the approaches are conducted using

software development process structures and patterns, such as the CMMI, ISO/IEC (International Organization for Standardization / International Electrotechnical Commission), SWEBOK (Software Engineering Body of Knowledge), and game theory frameworks that facilitate the interaction between players in a SPI initiative.

Table 2: The problems in the SPI initiatives.

1. Focus on certification instead of focusing on improvement.
2. Lack of government incentive.
3. Reduction in consulting hours as a way to reduce costs.
4. Lack of knowledge of the importance of models by the market.
5. Lack of / few projects to validate an improvement program.
6. Bureaucracy in improvement programs.
7. Continuity of team engagement in the defined process.
8. Lack of / little knowledge of the models by employees.
9. Different interpretations regarding the models.
10. Lack of consistent project portfolio planning.
11. Lack of consistent planning by the top management of the organization.
12. Lack of flexibility of the models.

5 DISCUSSION

This section presents our main conclusions and impressions of the results presented in Section 4.

First, it can be observed that gamification can be used to solve or minimize problems faced in SPI initiatives according to selected studies and related works (in Section 7). The gamification elements identified can be used when organizations are facing these issues, not limited to a specific scenario. However, there is no research according to the selected studies and related works in which gamification can be verified in a real scenario of the SPI initiative, or even compared with a framework of initiatives such as CMMI, ISO/IEC, SWEBOK and other approaches.

According to the results listed and described in this study, it is possible to affirm that there is an interest on the part of academia and the software industry in developing research focused on gamification, especially research that focuses on approaches to SPI.

6 THREATS TO VALIDITY

This section discusses potential threats to the validity of this paper and actions taken to address validity issues. We used the structure proposed by Wohlin et al. (2000).

6.1 Construction Validity

To minimize the risk that the SLR would not bring the studies that answered the research questions, a test was carried out with the search string. Four studies that proved to meet the research objectives were manually selected and then it was verified if, when running the string in the bases, these same studies would return, which in fact happened.

6.2 Internal Validity

During the extraction process, studies were ranked based on our judgment. Studies that depend on the judgment of the authors can carry with them a bias that needs to be mitigated as much as possible. With that in mind, throughout the study analysis process, weekly meetings were held to discuss and reach a consensus on which studies should really be selected.

6.3 External Validity

It is possible that SLR does not return all relevant studies on approaches that support to solve SPI problems. To mitigate this risk, we identified and relied on studies similar to this one so it wouldn't start from scratch.

6.4 Validity of Conclusion

To ensure the validity of the conclusion of our study, we present the results generated directly from the data and discuss the observations and explicit trends. This ensures a high degree of traceability between data and conclusions. In addition, our corpus of studies is available to other researchers. Furthermore, the SLR process was carried out with the support of two PhD professors who have extensive experience in studies of this genre, with several publications in software engineering.

7 RELATED WORKS

This section presents similar studies that are directly or indirectly related to the investigation of the present study.

Herranz et al. (2013) present an approach to managing change in SPI initiatives, based on the use of gamification techniques to support SPI processes. The authors highlight change management as one of the important areas to be controlled. In this way, they direct greater care to managers, since their actions are essential in the improvement of the software process and their commitments and support are essential to obtain the benefits of a software process. However, the authors present a gamified approach more focused on top management, without addressing other gaps that are perceived during the implementation of the improvement.

In the work by Herranz et al. (2014) a gamification framework oriented to the needs of the organization and the groups of software professionals involved in an SPI initiative was defined. To establish an adequate gamification framework, the authors emphasized the need to adapt the motivational factors of each of the software professional groups. Although the authors build a gamified structure to help different groups of professionals, the approach did not specify elements that should be used as possible solutions to the problems that professionals would face, since the structure to be used depends primarily on the initial study of the people who will be involved. in the improvement initiative.

To validate the gamification structure presented earlier, Herranz et al. (2016) used a structure adapted to the particularities of an organization and software professionals to encourage motivation. In this validation, a qualitative research methodology was employed through interviews that involved a total of 29 experts in gamification and SPI. The results of this study confirm the validity of the presented framework, its relevance in the field of SPI and its alignment with the standard practices of gamification implementation in organizations. The results obtained in the study were relevant to support the use of the gamification approach in the context of SPI, however the structure was adapted to the particularities of an organization and specific professionals, so it cannot be generalized to other organizations, since the authors are unaware of their needs. This perception is in opposition to what was exposed in the work previously, of creating a structure adapted according to the scenario of the organization.

The study by Herranz et al. (2018) aimed to bridge the gap between gamification in SPI and empirical evidence by presenting the implementation of the SPI gamification framework in a real environment. The framework validated in the authors' previous work was adjusted and implemented in a small Spanish software development organization, in a controlled experiment, focusing on a team competition (experimental group) to validate its effectiveness. The implementation results show that the application of the structure does not increase staff motivation in SPI tasks, although it contributes to improving their performance. Therefore, the authors point out that the results obtained are a consequence of the use of competitive game mechanics, which may have caused tension between the participants, and this fact can reduce motivation and fun.

Soares (2020 and 2021) present a systematic review of the literature, where problems or difficulties detected during the implementation of MPS and gamification elements for the treatment of these problems are analyzed. The problems were conducted from two perspectives, analyzes carried out in the literature and another from the analysis of results obtained from the application of a survey.

Marougkas et al. (2021) proposes the improvement of teaching and learning methods through a framework based on virtual reality, gamification and adaptive design according to the student's profile, aiming to make learning procedures more fun, engaging and effective. The method proposed in the creation of the framework can serve as a basis for the design of the applicability guide using gamification in SPI.

In this way, we can see that although the studies dealt with in the SLR did not answer all the research questions; the related works presented in this section can be used as a basis for collecting this information.

8 CONCLUSION

This study described an SLR to identify problems during the implementation of software process improvement and how to use gamification to solve and / or reduce problems and difficulties that organizations face during the implementation of SPI. We selected 7 primary studies, from 2011 to 2021.

From the results, it was possible to verify how scarce the use of approaches and elements involving gamification for SPI is, despite the studies describing gamification as a tool in several areas of software engineering and SPI, in addition to being

able to see some limitations that still must be mitigated, which therefore provides opportunities for researchers in the area to develop further, using the experiences presented in related works.

This SLR will serve for the next stage of research, as an instrument for the elaboration of an applicability guide using the gamification elements described by Soares (2021) in software organizations. In this line, we plan future works to use gamification as a tool to mitigate barriers during the implementation of an SPI initiative in a company that opted for an SPI framework such as CMMI and / or MPS.BR, and to develop a guide of applicability using gamification in SPI so that it can be used by software organizations.

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