

# The Use of a Framework to Support Gamification Evaluation in Knowledge Management Teaching in Software Engineering

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**Abstract**—This Research to Practice Full Paper presents that the use of gamification – the adoption of game elements in non-game contexts – is a recurring theme in software engineering education literature in the last decade. Gamification has been largely used to increase the engagement and motivation of students and professionals in their organizations, with a variety of models/frameworks for developing gamified approaches. Studies report positive and negative outcomes from the adoption of gamification. However, generalization is difficult because: (i) the evaluation data are heavily coupled to context and individual characteristics of participants, (ii) there are often insufficient detail on the design of evaluation procedures, hampering replication, (iii) there is lack of significant statistical data and imprecision of qualitative data, and (iv) there are no standard models in use to support the evaluation of gamification, hence there are no standardization in design, data analysis and report of gamification evaluation. The empirical data published so far are not sufficient to elucidate the phenomena resulting from the use of gamification, as there is no standardization in the specification of evaluation strategies, methods of analysis and reporting of results. Therefore, the objective of this study is to present and discuss the use of a framework for the evaluation of gamification in the context of software engineering education and training. For this, we executed a case study, in which the framework was used to support the design of an evaluation study for a gamification case in a knowledge management research group in a public university. Our main findings are: the framework helped streamlining the design of the evaluation study, considering the consistency between data to be collected, evaluation questions, and the goals of the evaluation study, that different rounds of analysis are supported, and that analysis of data relating to one evaluation question can complement analysis of other questions.

**Index Terms**—software engineering education, gamification, framework, evaluation, case study

## I. INTRODUCTION

There are many models, frameworks and processes to support the design of gamification strategies in many areas, such

as software engineering, business, healthcare, crowdsourcing and education [1]. In addition, there are studies that report positive and negative results from the use of gamification [2], [3].

However, as evaluation data are strongly associated with the context and individual characteristics of each study [2], there is insufficient detail on the design of evaluation procedures, making replication difficult [3], and there is a lack of data significant statistics and imprecision of qualitative data [4], it is not possible to generalize such results.

These gaps may be related to the absence of standard models in use to support the evaluation of gamification, despite the fact that there are many studies that evaluate their gamified approaches [5].

Therefore, the objective of this paper is to report and evaluate the use of an evaluation framework for gamification. To achieve this objective, we describe a case study in which we observed the use of the framework to support the design and execution of the evaluation of a gamification case in the context of software engineering education and training, specifically in the context of knowledge management. The gamification case was designed to discuss and record knowledge related to software process improvement (SPI) in the context of a research group at a public university. As a result, we provide a set of findings, with recommendations for the design and report of studies evaluating the use of gamification for teaching software engineering, based on this experience of using the framework.

The rest of this paper is organized as follows. The Section II presents the framework for evaluating gamification. The Section III presents some related works. The Section IV presents the study design and methods. The Section V reports the execution of the case study. The Section VI presents

and discusses the case study evaluation and recommendations for designing evaluation studies for gamification approaches in software engineering. The Section VII presents potential threats to validity and mitigation strategies. The Section VIII presents our final considerations, contributions, limitations and future work.

## II. FRAMEWORK FOR EVALUATION OF GAMIFICATION

The authors of [6] presented a conceptual framework for evaluating gamification in the context of software engineering teaching and practice. The purpose of the framework is to provide a standard framework for designing evaluation studies for gamification cases. The framework considers planning, execution, analysis and reporting of results. As an expected contribution, the framework intends to support the production of empirical data that can be more easily compared.

Its design considers the results of a literature review [5] on the evaluation strategies used in gamification studies, and refinements in previous studies [6]. Its structure is based on the GQIM (Goal-Question-Indicator-Metric) model – a model that guides the design of evaluation metrics from the top-down analysis of the organizational objectives [7].

The framework is organized into evaluation stages and assessment entities. The evaluation steps describe a sequence of decisions that guide the review of the gamification project and lead its designer to reflect on the evaluation objectives, criteria, questions, required data and data analysis procedures. Evaluation entities are sets of these data and their relationship, which need to be documented for the evaluation.

Table I shows the components of the framework, mapping the evaluation phases to their respective entities.

## III. RELATED WORKS

To the best of our efforts, we found three studies that propose gamification models or frameworks, in the context of software engineering, with evaluation stages [8]–[10], as described in [5]. However, we did not find evidence of the adoption of these models to evaluate gamification cases. However, the framework used in the current paper (see Section II) is inspired by elements of the three models [8]–[10].

In addition to these models, we find studies related to the proposal of evaluation frameworks in different contexts. For example, [11] presents a framework for evaluating serious games in the context of teaching computing: MEEGA+ (Model for Evaluation of Educational Games). In the study, models are evaluated through case studies and surveys. Therefore, this study provided subsidies for the design of the case study described in this paper.

## IV. METHODS

This section presents the study methodology, describing its objectives, methods, actors and instruments. The aim of this study is to evaluate the adoption of a framework for gamification evaluation in the context of software engineering teaching and practice. To achieve this objective, we carried out a case study, consisting in the design of the evaluation of

a gamification project in the context of a research group on software process improvement, specifically in the context of knowledge management.

A case study is an empirical method focused on investigating a contemporary phenomenon in its real-life context, using multiple data collection methods, and without direct intervention (or active role) of the observer in the case [12].

The following subsections describe the actors involved in the study (Subsection IV-A), the study design (Subsection IV-B) and the instruments (Subsection IV-C).

### A. Actors

There are three roles involved in this study: researcher, observer and applicator.

The role of researcher is performed by three software engineering researchers (two PhD professors and a graduate student) who were actively involved in the framework design. The Researchers are responsible for planning the case study and analyzing the results of the observation of the case study.

The role of the observer is played by one of the researchers (the graduate student), responsible for supporting the applicator in understanding the framework and in collecting data on the use of framework.

Finally, the applicator is a graduate student who designed a gamification strategy and applies the proposed framework to plan an evaluation study.

### B. Study Design

The execution of the case study was carried out in four stages: planning, meetings, evaluation and analysis of the experience of using the framework.

**Planning.** This step consists of planning the case study, resulting in an initial schedule of meetings, design and selection of instruments and design of support materials.

**Meetings.** The applicator and the observer held eight virtual meetings. During these meetings, the first one used the framework to design an evaluation study for his gamification case, and the second helped in the understanding of the framework (on demand) and documented (text, audio and video) what happened at each meeting.

**Evaluation.** The observer interviewed the applicator (semi-structured interview) to collect impressions about the use of the framework.

**Data analysis.** The researchers analyzed the data from the records of the meetings and the evaluation phase, and drew conclusions to improve the picture.

### C. Instruments

Considering the restrictions imposed by the COVID-19 pandemic, the study was carried out remotely. All meetings were held and recorded using Google Meet. Google Docs was used to document meetings and produce meeting agendas and interview scripts. Google Sheets was used for data analysis.

The observer provided the applicator with previous work [6] describing examples of use of the framework, and a evaluation sheet – a structured electronic sheet for documenting the

TABLE I  
FRAMEWORK PHASES AND ENTITIES [6]

Evaluation Phases	Evaluation Entities
Contextualization of gamification	<i>Gamification</i> – game elements, description of the context, models and concepts used, approach objective of gamification, methods.
Definition of the evaluation scope	Evaluation – scientific research method, duration, population; Goals, Criteria and Evaluation Questions.
Definition of methods	Metrics, Indicators, and Data Collection and Analysis Tools.
Summary of results	Rounds – description and duration; Samples – demographics and size; and Data Collection (for each metric and sample).
Results analysis	Data analysis – results for evaluation questions; and Discoveries.

entities of the framework. These instruments were intended to support the understanding of the framework and support its use.

## V. CASE STUDY

This section describes running the case study. The Subsection V-A describes the gamification case considered for the case study, and the Subsection V-B reports the execution and results of each phase of the framework.

### A. Case Study Object

The object of study of the application of the framework is a gamified approach to encourage participants to create, evaluate and perceive the knowledge produced within a research group at a Brazilian Federal University.

A gamified approach is used, based on a gamification framework specifically aimed at the knowledge management context [13]. In this gamification, the case study participants discuss the problems and solutions of software process improvement within a software engineering research group, to produce and manage knowledge. In this approach, game elements such as mechanics, dynamics and components are used. If applied together, these game elements allow the realization of a gamified experience [14].

Six undergraduate and graduate students from the research group participated in the gamification case for four weeks. The designer of the gamification strategy (the applicator) used the framework for evaluation with the same purpose of the previous study, to evaluate the impact of his gamification case.

### B. Case Study Report

The case study was carried out in five meetings. The subsections below report the execution and results of each step of the framework as performed by the applicator.

1) *Contextualization of Gamification:* After the first meeting, the observer presented the structure of the framework to the applicator, and asked a series of questions about its use. Now, the applicator has documented the context of his research and the purpose of gamification by solving a series of questions designed for the applicator to pay attention to important information about gamification, potentially relevant for the subsequent design of his evaluative approach. This question sheet was used in the stages of contextualizing the gamification and defining the scope of the evaluation, defining methods and summarizing results. Table II presents

the documented data. Below is the list of questions used to conduct the documentation of this evaluation step.

- 1) What is the context of gamification?
- 2) What is the purpose of the activity to be gamified?
- 3) Describe the gamified approach.
- 4) What is the objective(s) of this gamified approach (objective)?
- 5) Why is the design of this gamified approach “appropriate” to achieve this(these) goal(s) (justification)?
- 6) How will this approach be applied (method)?

TABLE II  
CONTEXTUALIZATION OF GAMIFICATION

<b>Context</b>	Software Engineering Practice – Managing the knowledge
<b>Name</b>	A gamification framework [13]
<b>Description</b>	Subsection V-B1
<b>Objective</b>	Encourage participants to create, evaluate and understand the knowledge produced
<b>Elements</b>	All presented in the gamification framework

2) *Definition of the Evaluation Scope:* At the next meeting, the applicator answered the questions on the evaluation form referring to the evaluation scope definition stage. It included: research method (case study and action research), population sampling (research group members), study duration (four weeks) and a set of metrics. Based on its gamified approach, and by answering the questions corresponding to this stage of the evaluation form, the applicator can make evaluation decisions focused on a single objective: to evaluate how the methodology adapted from his framework [13] is aligned with IT (Information Technology) courses. Below is a list of questions present at this stage.

- 1) What is the search method adopted?
- 2) Describe the population to be evaluated.
- 3) Enter the duration.
- 4) What is the objective(s) of this evaluation? (Objective)
- 5) Which evaluation criterion(s) can be adopted?
- 6) What question(s) is this review intended to answer?

Table III presents the basic information of the evaluation study.

The evaluation considered 9 criteria:

- **Performance:** Knowledge production based on SPI problems identified in the previous case study,

TABLE III  
DEFINITION OF THE EVALUATION SCOPE

<b>Method of Research</b>	Case Study and Action-Research
<b>Population</b>	Undergraduates and graduate degree in computer science, research group members for SPL
<b>Duration</b>	4 weeks
<b>Objective of Evaluation</b>	Evaluate as a gamified approach [13] is in line with IT courses.

- **Extrinsic motivation:** Willing to generate knowledge in gamified dynamics,
- **Engagement:** Participation and pro-activity in the proposed activities,
- **Awareness:** Realize the importance of the knowledge generated,
- **Communication:** Being involved with fellow participants in the discussion of the knowledge generated,
- **Efficiency:** Fluidity in dynamic activities,
- **Satisfaction:** Having their expectations met in the activities and having positive emotions generated during the activities,
- **Adequacy:** The importance of instruments used in gamification dynamics for knowledge generation,
- **Perception:** Realize the purpose of the gamified approach through dynamics, and realize his involvement in it.

For these criteria, the applicator proposed 11 evaluation questions. Table IV presents the relationship between the evaluation criteria and questions established by the applicator.

3) *Definition of Methods:* To define the evaluation methods, the applicator defined indicators and metrics, and documented them in the evaluation form itself.

Below is the question used in this step to induce evaluation design decisions to be made by the applicator:

- 1) What measures/metrics and indicators can be used to answer these questions?

To answer the evaluation questions, 18 indicators were developed, related to 20 metrics. Figure 1 shows an example of Criterion/Question/Indicator/Metric used in this evaluation<sup>1</sup>.

In addition, seven data collection and analysis instruments were defined, based on the measures adopted. For exclusively quantitative analysis: evaluation form, gamification worksheet, and knowledge cards. For exclusively qualitative analysis: observation and SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis. For qualitative and quantitative analysis: self-evaluation form and post-experiment questionnaire.

Due to the objective defined in the previous step, the applicator realized that he should review the evaluation provided for in the instance of his gamification framework to ensure its adequacy. Although its gamification framework provides for the use of SWOT analysis as an analysis tool for the evaluation

<sup>1</sup>The relationship of questions, criteria, indicators, metrics and instruments can be consulted at the link: <https://doi.org/10.5281/zenodo.5731447>

TABLE IV  
RELATIONSHIP OF CRITERIA AND EVALUATION QUESTIONS

Criteria	Evaluation Questions
Performance	Q1. What is the relationship of knowledge items produced and approved by the research group? Q2. How participants perceive their own performance during the experiment?
Extrinsic motivation	Q3. Did the gamified approach increase the participants' motivation in the habit of producing and evaluating knowledge?
Engagement	Q4. Did the dynamic participants engage in knowledge production and evaluation activities?
Awareness	Q5. Did the participants perceive that the knowledges produced by themselves, and by others, are important and has an impact on research group's business?
Communication	Q6. Did the participants communicate during the dynamics? Did communication favor the production of knowledge?
Efficiency	Q7. Were the dynamics applied during the gamification fluid, that is, did they occur without delays, without problems, without impediments? If not, why did these delays occur? What problems arose? Do they impact the production of knowledge? What are the most common problems?
Satisfaction	Q8. Did the participants show satisfaction after applying the gamified dynamics?
Adequacy	Q9. Do the instruments and activities developed fulfill the purpose of stimulating knowledge management?
Perception	Q10. Did the participants understand the purpose proposed for the gamified approach? Q11. How did the participants perceive their socialization process in the gamified approach?

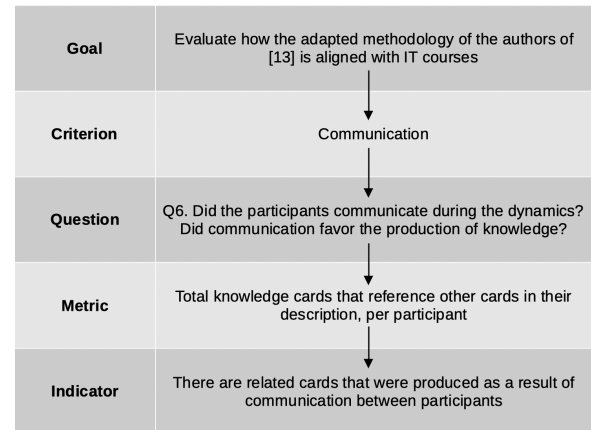


Fig. 1. Example of goal, criterion, question, indicator and metric, according to the framework

of the instruments used in the gamified approach, this method did not cover the evaluation of all the defined criteria. Of these, the SWOT analysis would be used to assess only the criteria of efficiency, satisfaction, adequacy and perception.

4) *Summary of Results:* This stage took place during the five weeks dedicated to the execution of the evaluation study<sup>2</sup>, when the applicator collected data to calculate the metrics defined in the previous stage. For each round of the evaluation

<sup>2</sup>The applicator had to add another week to the case study

study, the applicator documented all data collected using the same evaluation form used to define the evaluation methods.

Table V presents information about each round of the evaluation study. The rounds were conceived as 'cycles', in which participants had to carry out specific activities (described in the "Description" column).

TABLE V  
SUMMARY OF RESULTS - ROUNDS

Round	Description	Duration
Pilot	Presentation of dynamics, and simulated round	2 hours
Cycles 1-3	Iterations of generation and discussion of knowledge	6 hours
Evaluation	Evaluation and Feedback	2 hours

It was decided to define a matrix for summarizing the results for each measure, instead of for each round, as the applicator considered that the new form of tabulation would be smaller and easier to read. Below is a summary of the measures adopted.

- Evaluation form, gamification worksheet, knowledge cards, self-evaluation form, observation and SWOT: Participants X Rounds
- Post-Experiment Questionnaire: Participants X Questionnaire Questions

5) *Analysis of Results*: However, in the analysis stage, the applicator found it more prudent to analyze only the data related to the resolution of two evaluation questions, and in two analysis and collection instruments (Q8 - Self-evaluation form, Q9 - SWOT), due to such a large amount of data available in all collection instruments.

The objective of this stage was to obtain answers to the two evaluation questions focused by the applicator, from the analysis of the data collected by the self-evaluation form and SWOT analysis instruments. In that study, the applicator used qualitative analysis to answer the evaluation question Q9. Also in this same study, the applicator used affective analysis (qualitative and quantitative) – that is, through the emotions perceived in speech [15], such as the textual in the case of this study.

The applicator chose not to use the framework "Analysis" and "Find" entities to draw conclusions directly. Independently, he carried out deductive analyzes based on the evidence collected in the two instruments used, and drew conclusions about the object of study from these analyses.

## VI. EVALUATION OF THE FRAMEWORK USAGE

This section describes the analysis of the case study reported in Section V. After the conclusion of the case study, an interview was conducted (Subsection VI-A), and a summary of the findings obtained from this case study (Subsection VI-B).

### A. Interview

After summarizing and analyzing the results referring to the two evaluation questions presented, the observer interviewed

the applicator in order to collect his impressions about the use of the framework. The interview focused on the relevance of the framework in the evaluation carried out by the applicator.

**Observer:** "Which entities from the framework did you use?"

**Applicator:** "All. Actually, I did not analyze all the data, as I was focusing on writing an article. I summarized all the data collected by the instruments. However, after discussing with my advisor, we decided to focus in solving only two evaluation questions for the writing of this article, because there was a lot of data. However, I will use the other data to answer the remaining evaluation questions. I got all the information from using the evaluation framework it was relevant. Despite not using all the data now, I needed a greater level of detail (in the evaluation), provided by the framework. Using it, it is possible to define criteria, and to know why the use of these and other items that derive."

From the applicator, it is possible to infer that the postponement of the analysis of the other summarized data was motivated by a research decision, in a broader scope than the evaluation of this case study.

The next question is related to the evaluation steps, aiming to know if the applicator understood the purpose of its execution sequence.

**Observer:** "Regarding the evaluation stages, what purpose can you extract from them?"

**Applicator:** "I realized that there was a flow, where one step would complement the other, as a basis for the next. This organized my ideas. I could see the evaluation more clearly in a more general aspect."

**Observer:** "Even so, did you have any difficulties performing these steps?"

**Applicator:** "Actually, there was a weak point that is also a strong point. The dynamics were a bit extensive and full of rules. This made it more difficult to summarize, generating a bit of extensive documentation. This is bad in the sense of consolidating the evaluation, but it is also positive because it brought me a lot of information."

It can be seen that the applicator understood the sequence of steps, and the way in which they were carried out (solving questions on the evaluation form) made the decisions made for the evaluation design aligned with the objective of the dynamics. However, although the level of detail provided by the entity framework makes the documentation extensive, this is not seen as an impediment to using the framework.

The last question of the interview obtained information about the findings, since the summarization and analysis information of the results had not been shared with the observer. The purpose of this question is to consolidate the relevance of the framework in obtaining findings in case studies.

**Observer:** "About your results, what is the main finding you obtained in this evaluation?"

**Applicator:** *"By relating the analyzes performed to answer each question, I could see that one analysis explained the occurrence of the other: a drop in participants' self-evaluation between the first and second cycle of knowledge generation, which made me worried. However, this self-evaluation improved in the third cycle. When answering question Q9 (SWOT analysis), where participants give their opinion on the instruments used, I found that this was related to the participants' frustration when they did not reach the goals of cycle 2, established by themselves in cycle 1, reaching them in cycle 3. With this, I conclude that the dynamics encouraged the definition and achievement of goals."*

With this, it can be seen that the relationship of dependence between analyses, collections, measurements and evaluation questions allowed a comparison of results capable of generating findings that explain a phenomenon not foreseen in the design of the gamified approach. Knowing that the premature estimation of goals to be reached in a first cycle, the applicator can adapt its dynamics so that this does not happen in other case studies where he uses his framework of gamification.

## B. Findings

From the observations and results of the interview, it is possible to list the following findings in the use of the framework in this case study:

- 1) Evaluation work products: the use of the evaluation form, composed of a series of objective questions, as a tool to guide the use of the framework and document project decisions was positive. The use of an evaluation worksheet, which structured the evaluation approach, to specify the relationships between evaluation questions, measures, indicators, metrics and collection and analysis instruments, was also positive.
- 2) Rationalization of the evaluation design: the framework helped to simplify the design of the evaluation study. It provided a sequence of decision-making actions that required the design of an evaluation study considering the consistency between the data to be collected and the evaluation questions, and between the evaluation questions and the objectives of the evaluation study.
- 3) Partial analysis: despite collecting and summarizing the data at once, it is possible to perform partial analysis of the collected data. With this, data analysis cycles can be done, as long as the analyzes are aligned with the evaluation questions that can be answered with the analyzed data.
- 4) Related analysis: it is possible to infer causal relationships between the analyzes of different evaluation questions. As in this case study, this may allow the generation of important findings to improve the gamified approach in future applications.
- 5) Freedom of data analysis: through its structure, the framework induces the deductive analysis of the data for the resolution of evaluation questions, objectively.

However, this does not prevent the applicator from using new forms of data analysis. The use of affective analysis had not been foreseen until the last meeting, but the summarization of the data allowed the use of this analysis approach.

## VII. THREATS TO VALIDITY

This section describes potential threats to the validity of this research step. The categories proposed by [16] were considered: conclusion, internal, external and construct. At each stage of the study, we sought to systematically identify and mitigate possible threats to the validity of each one, seeking to ensure that each activity provided safeguards for the following [17].

**Planning.** This phase was threatened by internal validity bias. It is possible that the use of the methods and instruments defined during the planning stage in the meetings was not necessarily related to the success, or failure, in the process of designing the evaluative approach of the case studies, as the applicators could have designed their evaluative approach independently of the framework instantiation. To mitigate this, the observer had the role of monitoring the use of the framework during remote, recorded meetings. Furthermore, all the work products produced for the framework instantiation and evaluation were shared between the applicator and the observer of each case study, in order to verify if what was produced was related to the use of the framework.

**Meetings.** During meetings, there are internal and completion threats to validity. The framework applicators may have incorrectly instantiated the framework, which can make it impossible to summarize and analyze the results (Internal threat). To mitigate this, the researchers reviewed the documented data and their interpretation of it, and requested revisions where necessary. This solution could have generated a threat of conclusion if there were suggestions from the observer, interfering with the collected results. However, this was mitigated because the researcher with the observer role only spoke during the meetings to expose the possibilities of instantiating the framework, and the other researchers only spoke with the observer again after the evaluation stage was completed, to comment on the evaluation.

**Evaluation.** The threat to construct validity is the inadequacy of interview questions to the reality of case study execution. To mitigate this, an initial script was used, with a semi-structured interview being carried out, admitting modifications to the original script to obtain more meaningful responses to the evaluation of the case studies.

**Analysis of results.** There are threats to completion. The researchers may have generated inaccurate analyzes of the collected data. To alleviate this, these results were discussed in a committee between PhD researchers (advisors) and the observer (student) where there was discussion about each of the items raised, and the analysis was only performed with the confirmation of the 3 researchers. In addition, excerpts from interview transcripts and survey data are presented in the Sections V and VI.

## VIII. CONCLUSION

This study presented a report on the use of the framework in a case study for the evaluation of gamification in the context of education and training in software engineering. From the analysis of the experience with the use of the framework, it is possible to perceive that the applicator of the case study was able to improve the design of an evaluation study and obtain positive results with the use of the framework. From this experience, it was possible to extract a set of recommendations for the framework, which can help future works in gamification and software engineering in the design of an evaluative approach suited to your study context.

A limitation of this study is the lack of evaluation of each evaluation item and instruments defined during the case study. Furthermore, the recommendations were taken from only one experience of using the framework and therefore cannot be generalized. For future work, we intend to prepare and evaluate a list of instructions for using the framework, recommendations and instantiation examples. Furthermore, it is intended to validate the framework from new analysis of gamification evaluations, which can be performed using this instruction sheet.

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