Assessment of a Gamified Automotive Software Development Environment

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Abstract. Gamification is a new strategy that allows influencing and motivating people mainly in two types of activities: 1) to develop activities that people are not used to performing, or 2) to let people acquire new habits. Besides, it has been proven to have good results in its implementation in non-context fields such as healthcare, education, and marketing, among others. This fact makes gamification attractive to be implemented in the software process improvement field. However, the results to implement gamification in the industry are not yet commonly published. This paper shows the assessment of a strategy implemented in a software development automotive environment. The results allow analyzing the level of the gamification achieved by the strategy. Besides, some recommendations to reinforce the strategy for future implementation in this type of environment are provided.

Keywords: Automotive · Gamification · Strategy · Software development organizations · Assessment framework

1 Introduction

The gamification term should be understood as the use of game elements in a non-game environment. It aims to obtain better experiences and the commitment to people using it [1].

The importance of gamification has been increasing in the last few years because it provides an alternative tool to create strategies focusing on developing a new activity or on acquiring new habits while increasing teamwork motivation and commitment [2].

This fact makes gamification very attractive for reinforcing software engineering activities because it has demonstrated a high level of motivation, an increment in technical knowledge, and in-progress indicators of a project's teams [3, 4]. And within this

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area, gamification has been focused on Software Process Improvement activities due to personal importance [2, 5].

Therefore, as mentioned in [5] it is necessary to analyze the effects of gamification in the Software Process Improvement (SPI) field, however, there are not many results or evidence of the implementation in the industry for Software Process Improvement.

This is the case in the Automotive industry sector around the world has been experimenting with a steady restructuring process, which has made it one of the most dynamic industries of the modern age. This restructuring is mainly focused on the technological innovation applied to operational processes and human factor organization, and in the market reconfiguration.

The importance of quality software for the Automotive industry, and is because software development is one of the major parts of the Automotive projects which takes the focus of the Original Equipment Manufacturers (OEMs) since the software was representing 40% in 2010 of the vehicles (see Fig. 1).

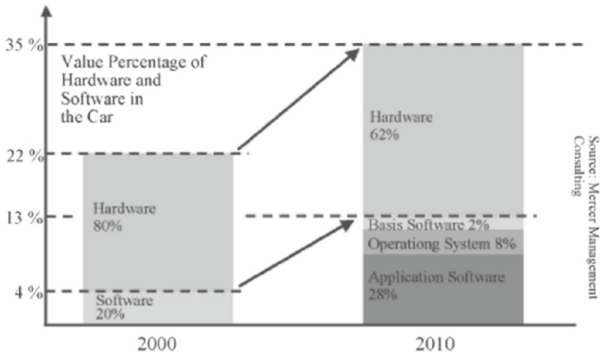

Fig. 1. Value percentage of hardware of software in a car.

Statistically, this number has been rapidly increasing in 2021 to reach more than 60%, which shows the need for OEMs to focus on this component, especially when we talk about the advanced automotive SW technologies, like Artificial intelligence, Cyber Security, and Model-Based Development.

For this reason, for automotive organizations providing high-quality products is a key element to creating, protecting, and enhancing the organization's reputation, competitive advantage, customer satisfaction, and increase the market input.

Besides, most of the automotive car makers or Original Equipment Manufacturers (OEMs) are requesting the automotive suppliers to have at least a SPICE CL2 to assign projects to them so that a high-quality product can be ensured. Unfortunately, the actual status of the majority of the automotive suppliers is at CL0 or even CL1.

This fact highlights the need to implement software process improvement initiatives in automotive organizations. However, due to the specific features of this industry such as (1) limited time, (2) fast change in technology, (3) Original Equipment Manufacturer (OEM) focuses on applying certain international standards, and (4) projects complexity (in terms of distributed development and sensitive programming), it is necessary to use

attractive strategies to keep engineers motivated and engaged to participate in system and software process improvements initiatives such as gamification strategies.

In this context, this paper focuses on contributing to the state of the art by presenting the results of assessing a gamification strategy implemented in an automotive software development environment.

The framework to assess the gamification strategy used in this paper is a previous work of some of this paper's authors [2]. The framework allows evaluating a strategy to implement gamification elements, components, and principles [2]. The assessment framework covers two purposes: (1) in the inductive purpose, it aims to identify the adoption of gamification elements, and (2) in the deductive purpose, it aims to verify the accomplishment of gamification fundamentals in an existing gamified environment.

The rest of this paper is structured as follows: Sect. 2 presents an overview of implementing gamification in the industry and the description of the context of the software development in the automotive industry; Sect. 3 presents the method implemented to assess the gamification strategy; Sect. 4 presents the results; Sect. 5 provides a discussion, and Sect. 6 highlights the conclusions and future work.

2 Overview

This section provides an overview of approaches that have reported the use of gamification in the industry and the context of the software development industry in which the gamification strategy evaluated in this paper was implemented.

2.1 Implementing Gamification in the Software Industry

Pedreira et al. [6] present a systematic mapping of the use of gamification in software engineering (SE) from 2011 to 2014. This study highlights that although there are proposals to incorporate gamification in this area, these are still preliminary, and it is necessary to work more on the impact of gamification in SE. Such fact is one of the motivations of our work, contributing to assessing the use of gamification in a specific industrial sector (automotive industry). Additionally, these authors affirm the necessity of incorporating gamification in other software engineering subareas such as Requirements Engineering, Project Management, and Testing.

Subsequently, de Paula Porto et al. [7] analyze 103 studies to characterize how gamification has been adopted in non-educational contexts of software engineering activities. They conclude that gamification in SE is a growing research area and the main benefits in the experiences revised are the increased engagement and motivation of doing tasks by software development teams.

Considering that gamification can contribute to increasing software engineering productivity in software development teams, Ren, Barrett and Das [8] built a general gamification process model for the software development lifecycle including metrics to quantify the contribution of each team member to the project goal. This model is implemented in a gamification environment for developers integrated into the project GitHub repository to assess individual developers project phase contributions. This work corresponds to another example of the importance of not only using gamification in industrial environments but also measuring its impact.

In a gamification platform for software process improvement [9], Herranz, Colomo-Palacios, and de Amescua Seco report how through a web platform the concept of gamification can be applied in software development activities to improve the participation of workers in Software Processes Improvement (SPI) activities. This paper highlights the lack of participation of workers in SPI activities and provides, as a result, a tool based on a web platform to promote the worker's participation. The goal of this proposal is to use gamification elements to measure the impact of the proposed platform on the motivation of software development practitioners that applied SPI activities. Their main results show that workers had an increase in their participation in the improvement of software processes.

In a simulation and gamification approach for IT Service Management Improvement [10], Orta and Ruiz proposed a conceptual framework that aims to improve processes related to information and technology services management. The framework is based on building simulation models and gamifying the model to increase the motivation and engagement of IT managers'. In this way, it was possible to address the IT managers behavior toward the achievement of established objectives. The framework was implemented in a banking validation services provider and an e-commerce company. As the main results, they highlighted that the framework enables IT managers to know the effects of process changes before their implementation in the organization so that they could make better decisions. Besides, the use of gamification for the simulation model increases the IT manager's motivation because they were able to know their progress and receive rewards for reaching the established objectives.

Sherif et al. [11] used gamification to encourage students to develop better software testing habits looking to be the learning experience more engaging and enjoyable. They develop a turn-based game called CoverBot where the players act as a character whose survivability depends on how effectively the player can execute all lines of code in a given level with the fewest number of inputs possible. Such game includes gamification features like level progression, a scoring/combat system, animation, and sounds. The authors conduct a user study showing that is possible to measure the engagement, enjoyment, and performance of game participants.

In this same sense, Mesquida et al. [12, 13] propose the use of collaborative games for the institutionalization of best practices recommended by agile methods. Moreover, these authors present a collaborative game toolbox to use in software development teams' meetings. Another research shows the use of such games for software process improvement in the areas of project management and software implementation through the application of a business game to the activities suggested by ISO 21500 international standard [14]. Finally, Jovanovic et al. [15] also describe the incorporation of a game in retrospectives in agile software development teams looking to facilitate the selection of process improvement activities including technical and human project factors.

2.2 Gamification Application in the Automotive Industry

Gamification has become a widely used strategy to promote aspects associated with important characteristics of work teams. Their use is reported more frequently in areas such as marketing, finance, human resources, environment, government, and software

development. Being the gamification increasingly common in education, health, and the service industry [1, 5, 9, 10, 16].

However, in the automotive industry, few reports are presenting the use of gamification [17], which indicates a potentially active area to be explored. Therefore, it requires proposals where gamification can be used for the benefit of this industry. In this context, Korn et al. present a study related to the general acceptance of gamification in modern production in the Automotive Industry, this study reported good results that demonstrate the importance of exploring gamification as an alternative in the automotive industry [18].

Moreover, one of the most famous initiatives of applying gamification is the speed camera lottery of the fun theory, an initiative carried out by Volkswagen by the end of 2010 [19]. This strategy was one of the winners of the Fun Theory Award. The Speed Camera Lottery consists of a machine that photographs those who are driving both within and above the speed limit. Law-abiding citizens are automatically entered into a lottery, while those who break the law are issued citations. The best part is that the cash reward for the lottery winners is funded by the fines paid by those who broke the law.

Another study, which reviewed the current body of academic literature concerning the implementation of gamification in production and logistics, reports that the most common sectors using gamification were the automotive and construction industries [20]. In the automotive industry, gamification was mainly targeted at a variety of assembly tasks, but this study does not include software development as a study area. Besides, the gamification interface in the bolt-tightening work on the automotive assembly line is another interesting proposal [17]. This proposal is related to generating an experience in workers' gradual goals, receiving feedback through an audio-visual mechanism, and having a progress bar.

In summary, it is possible to identify interesting proposals about the application of gamification in different industries, especially when gamification is treated as a strategy to process improvement. The above is reinforced by studies that analyze the main applications of gamification from the interests of Industry 4.0. In this report, the automotive industry was identified as the industrial sector with more gamification use, within the sample of practical researchers in the studies [16].

3 Assessment Framework

This section presents the framework to assess gamification strategies. The framework allows establishing the gamification level achieved by an implemented strategy. To achieve this, it includes an assessment gamification model and a software tool.

On the one hand, the gamification model provides a set of elements such as variables, and a set of equations or rules for obtaining gamification level indicators to verify if the gamification principles identified and adopted in the designed strategy are implemented properly. Table 1 shows a summary of the used elements.

Table 1. Model elements used in the tool to assess the strategy.

Symbol	Variable name	Description	Equations or rule
W_{id}	Principle weight	Sum of the assessment of each evidence multiplied by the grade of incorporation of each gamification principle identified	$W_{\text{id}} = \left(\sum Tlg + r + m + Tru + s\right) * Gr_{id}$, *where id = principle identifier*
LW_{id}	Gamification level	Percentage of incorporation of gamification of the environment under assessment	$LW_{id} = \frac{W_{id} * 100}{5000}$
Tlg	Total learning goals	Number of learning goals identified in the game elements that are described in layer design in the framework [2]	$Tlg = \left(\frac{40}{n}\right) * x$, *where n = quantity of learning goals and*, x = *quantity of learning goals for each principle*
Tru	Total rules	Number of game rules in the game elements that are described in layer design in the framework [2]	$Tru = \left(\frac{30}{m}\right) * y$, *where m = quantity of rules and*, y = *quantity of rules for each principle*
r	Roles	Indicate the roles identified in the game elements that are described in layer design in the framework [2]	$r = 10$
m	Materials	Indicate the materials identified in the game elements that are described in layer design in the framework [2]	$m = 5$

(*continued*)

Table 1. (*continued*)

Symbol	Variable name	Description	Equations or rule
s	Steps	Indicate the steps identified in the game elements that are described in layer design in the framework [2]	$s = 5$
Gr_{id}	Grade	Identification of evidence of the level of incorporation of each principle in the environment under assessment. For achieving this grade, a qualitative assessment scale was defined according to a Likert scale	Null: There is no evidence that the principle is fulfilled or is present in the gamified environment Medium: There is some evidence that the principle is fulfilled or is present in the gamified environment and it is possible to identify at least one element associated with this principle with some difficulty Significant: There is some evidence that the principle is fulfilled or is present in the gamified environment and it is possible to identify at least one element associated with this principle High: There is evidence that the principle is fulfilled or is present in the gamified environment and it is possible to identify the elements associated with this principle easily Very high: There is evidence that the principle is fulfilled or is present in the gamified environment and it is easily identifiable

On the other hand, the software tool is called Meejel (by its acronym in Spanish), its purpose is to automatize the use of the model components (variables, equation set, and measurement rules) for calculating the gamification level of an environment or strategy.

The calculation activity in the tool requires carrying out 3 actions next described:

1. *Create the strategy*: the user can register the strategy to be evaluated covering the three sections requested by the tool (basic data, gamification elements, and support material).
2. *Choose evidence for each gamification principle*: the user lists the evidence that the strategy can have related to the gamification principles [21]. The user should select the strategy to which evidence wants to be added and enable the corresponding switch. For each selected evidence, the user has available a text box of elements as well as the gamification level, which the user should select according to the registered evidence.
3. *List assessment results*: the user can view the list of strategies enabled, according to the user profile, which contains the corresponding gamification level (percentage).

To assess the defined strategy, we use the components of the model and the software tool implemented to support the model.

3.1 Gamification Strategy Implemented in an Automotive Software Development Environment

The gamification strategy evaluated in this paper was applied in an automotive software development environment. It is an environment in which the engineers follow a very rigid process for software development, and testing based on an incremental and semi-agile software development environment [22]. Besides, the gamification strategy is composed of two gamification practices:

1. *Raising the technical awareness:* this gamification practice has the scope to be used by the quality assurance team, which is composed of around 50 engineers. This gamification practice provides a challenge to divide the engineers into sub-teams. Each sub-team should choose a specific technical topic related to the system and SW development in the Automotive ecosystem to research and develop. Then, each sub-team should create a presentation to train the rest of the Quality Assurance teams (QA teams). The team winner is selected according to a satisfaction measure (highest satisfaction score). The winning team gets a celebration and some vouchers are given to the team.
2. *Top assessments achievers:* this gamification practice has the scope to be used by the employees of the organization are around 2000 engineers. This gamification practice is focused on identifying the achievements of assessment targets in the process assessments or original equipment manufacturers (OEM) assessments. In this case, the winner is the team, which achieves the target set for the internal processes assessments (e.g., ASPICE).

The model elements identified from the gamification strategy according to Table 1 are *learning goals, rules, roles, and materials*, and are next described:

Learning Goals: this element defines a set of the expected results in the implementation of the strategy. The strategy set six learning goals and its related proposed measure:

1. Raise the technical knowledge of the Quality Assurance (QA) team about the products.
2. Make more mature and realistic QA audits, so the project teams can have on-the-ground actions.
3. Create some ethical challenges between the QA team members, where they can compete and show their best regarding technical aspects.
4. Push the teams to do their best to achieve the customers and internal targets in terms of passing the process assessments successfully.
5. Reinforce the knowledge of the Requirement and Design teams (R&D Teams) about the existing processes.
6. Challenge engineers to identify gaps in the already existing processes to trigger some SW processes improvement (in some cases, engineers are too busy to think out of the box, due to their workload).

Rules: this strategy element defines a guide to the strategy execution. the strategy set two rules.

1. *QA team*: each sub-team selects a technical topic and thinks of an attractive way to market its session. Then, the team designs the materials and decides what will be the direction of the research.
2. *R&D teams*: set a strategy about how to achieve the processes assessments target, these teams work with the QA team to close the gaps related to compliance to Automotive SPICE expectations, and prepare the team for the assessment.

Steps: This strategy element defines the actions to be performed by participants. the strategy steps are divided into two groups as follows:

Practice 1. Raising the technical awareness

1. Each sub-team should select the technical topic related to the automotive system and SW development.
2. Find an attractive way to market it during the presentation session.
3. Design the materials and decide what will be the direction of the research.
4. Perform the technical training for the rest of the QA team.
5. Measure the percentage of the employee's satisfaction.
6. Recognize the winner sub-team.

Practice 2. Top assessments achievers

1. Establish a strategy about how to achieve the processes assessments target.
2. Work with the QA team to close the gaps.
3. Prepare teams for the assessment.
4. Collect the results of the process assessments (frequently).
5. Compare the results for all the teams.
6. Recognize the top achievers, in terms of processes assessment results.

Roles: the strategy was designed focusing on three roles:

1. *Quality Assurance team member (QA team)*: this role was covered by the quality team. For this team, the Raising the Technical awareness gamification practice was implemented. This role contains around 50 engineers.
2. *Requirement and Design teams' member (R&D team)*: this role was covered by the software development engineers for this team, the Top Assessments achievers, and the gamification practice was implemented. This role contains around 2000 engineers.
3. *Process improvement expert*: this role is focused on the chief assessments engineer of the company in charge of managing both gamification practices.

Materials: the strategy uses four types of materials:

1. *Recognition certificates*: printed certificates include the names of the winners & logo of the company to be posted on social media.
2. *Cups*: cups include the logo of the company for the winners.
3. *Recognition mails*: emails from management to recognize the winners.

4. *Post the winners' photos to the screens*: communication screens in the plant to display the photo of the winners.

4 Results

The results of the assessment are presented in Table 2 and relate to the qualitative level, weight, and evidence calculated from model components. In this table, it is possible to see that the strategy is related to all gamification principles included in the framework used to assess it. 6 of 10 gamification principles were assessed with a very high grade because all strategy elements explicitly include such gamification principles. In consequence, 4 gamification principles present different grades in their assessment because there is not an explicit relation with all strategy elements.

Table 2. Template to report the results of the gamification assessment model applied in the Automotive software development strategy.

ID	Principle name	Description of the principle to be assessed	Relation		Level	Weight	Evidence
			Yes	No			
1	Orientation	Gamified processes place the user (employee) at the center of the experience	×		Very High	450	Rules Learning goals Materials Roles Steps
2	Persuasive elements	Gamified processes include persuasive elements based on sound psychological and behavioral theories	×		High	93.33	Materials Steps Learning goals (LG6, LG3)
3	Learning orientation	Focus on knowledge acquisition, skill development, motivational outcomes, or behavior change	×		Very High	450	Rules Learning goals Materials Roles Steps

(*continued*)

Table 2. (*continued*)

ID	Principle name	Description of the principle to be assessed	Relation		Level	Weight	Evidence
			Yes	No			
4	Achievement based rewards	Focus on a justifiable and predictable return on investment	×		Very High	450	Rules Learning goals Materials Roles Steps
5	Y generation adaptable	Generation Y is the fastest-growing segment of the workforce and they are looking for work experiences that are supportive, fun, and engaging	×		Null	15	Roles Materials
6	Amusement factors	Inclusion of humor, play, and fun elements as part of the work processes	×		Significantly	75	Materials Steps Rule (R1)
7	Transformative	Use of a balanced and attractive combination of competition and collaboration to transform existing work processes within an organization	×		Very High	450	Rules Learning goals Materials Roles Steps
8	Wellbeing oriented	Focus on personal and organizational wellbeing	×		High	153.33	Materials Steps Rules (R1) Learning goals (LG6, LG4)

(*continued*)

Table 2. (*continued*)

ID	Principle name	Description of the principle to be assessed	Relation		Level	Weight	Evidence
			Yes	No			
9	Research generating	Collaborative research efforts must be encouraged to justify future investments in the area	×		Very High	450	Rules Learning goals Materials Roles Steps
10	Knowledge-based	Based on knowledge, either as an outcome or as feedback	×		Very High	450	Rules Learning goals Materials Roles Steps
Level						60.73	Partially gamified

The results of implementing the assessment model indicate that the principles of *Orientation, learning orientation, Achievement based rewards, Transformative, Research generating, and Knowledge-based* are the principles with the highest level according to the principles' weight. As a consequence of this weight, the evidence reported indicates that all strategy elements contribute to promoting these principles.

Regarding the principles, Persuasive elements and Well-being are principles reporting a high level with a weight of 93.33 and 153.33, respectively. In consequence of these weights, the evidence reported indicates that just some strategy elements promote these principles.

5 Discussion

Gamification is a growing trend where the human factor is fundamental in terms of motivation and engagement of the work teams. Such a trend can promote individuals' social interaction, quality, and productivity of their actions.

The above-mentioned highlights the importance of gamification and monitoring its performance, in this way the contribution of this paper is addressed. The results of the assessment of the gamification strategy allowed us to analyze aspects related to gamification principles to evaluate the performance of the strategy and based on that establish recommendations to improve it. According to the percentage of incorporation of gamification obtained in the strategy assessed, there were achieves a partially gamified environment with 60.73 points as shown in Table 2.

The principles identified to be improved in the strategy are amusement factors and Y generation adaptable as next described:

- Amusement factors are a principle related to the inclusion of humor, play, and fun elements as part of the work processes. According to this definition, the assessment results indicate that this principle has a significant level with a weight of 75. Following the evidence related to strategy elements, we can see that Materials, Steps, and only Rule 1 are identified as the elements promoters of this principle.
- Y Generation adaptable is the unique principle with a Null level according to the assessment model. This result is associated with the adaptation of younger employers to experiences supportive and engaging. In this case, the evidence shows that unique roles and materials elements promote this principle.

According to these results, it is possible to infer some recommendations and suggestions to reinforce the current Automotive software development strategy. These recommendations are centered on the principles with a weight under 80, i.e., Amusement factors and Y Generation adaptable as described in Table 3.

Table 3. Suggestions to reinforce the Automotive software development strategy.

Principle	Recommendations and suggestions
Amusement factors	• Gamification elements are an important part of a gamification strategy. For this reason, it is necessary to embed these elements in the gamification strategy activities. A structured way to identify and select gamification elements is to use classifications defined in [23] as Dynamics, Mechanics, and Components. Some elements that can support the Amusement factors principle in this strategy are described: • The emotional element integrates a set of emotional responses that are sought out in the gamification experience. Some of them may be related to curiosity, competitiveness, frustration, happiness, or creativity. It is part of the concept of fun [24]. This element also helps to increase the motivation of Y Generation participants, and some approaches include this element in the Dynamics category when they classify the gamification in the categories set • Considering that Mechanics is another important category to group the gamification elements, we suggest maintaining Rewards, Challenges, and activities associated with the Competition in the strategy. However, we recommend articulating these elements of the mechanics category with the dynamics category, specifically with the element of the emotions previously described • Another important category is Components; hence we recommend using gamification elements of this category as Badges that are already used in the evaluated strategy. However, we suggest including new elements such as Social Graphs and Voting articulately with other elements In summary, we purpose include and articulate more typical categories associated with gamification elements such as Components, Mechanics, and Dynamics. Specifically, we suggest articulating Emotions, Rewards, Challenges, Competition, Social Graphs, and Voting

(*continued*)

Table 3. (*continued*)

Principle	Recommendations and suggestions
Y Generation adaptable	This principle is defined as considering that this generation is the fastest-growing segment of the workforce and they are looking for work experiences that are supportive, fun, and engaging [17]. Thus, the new gamification strategies must contemplate technology to support the adaptation of this new generation that needs more fun and engagement in workplaces. Some examples are network games and software platforms such as Duolingo. However, software applications developed to support the strategy can be an excellent option, i.e., a championship online that includes the elements defined is an alternative.

6 Conclusions and Future Work

The implementation of Gamification strategies in the industry is not commonly published, this fact highlights the contribution of this research because we present a gamification strategy implemented in an automotive software development environment. Besides, the paper includes the assessment results of the gamification strategy and provides some recommendations to improve the strategy for the future. In this context, we will provide the conclusions of this paper focusing on: (a) lessons learned from applying a gamification strategy in an automotive software development environment; (b) using gamification in the automotive industry, and (c) the assessment of the strategy by using a framework, a model, and its software tool.

(a) *Lesson learned about applying a gamification strategy in an automotive software development environment:* the process improvement expert mentioned that they have noticed that the results of the projects have become better. Besides, the implementation of this strategy helps the engineers to be aware of the process, and as consequence, all of them speak the same process language that benefits the software development environment.

Besides, we have detected as the main barriers that organizations in the automotive domain have to applying gamification-related practices and strategies are: (1) the high workload that their engineers have; (2) the lack of time for thinking out of the box; (3) the high resistance to change; (4) the bad-well of the word "Gamification" because it is always linked to a game, which is not linked for business; and (5) there is a lack of a direct return for the engineer.

(b) *Lessons learned of using Gamification to help the automotive industry: as mentioned before, even when some barriers should be reduced*. The implementation of gamification in the automotive industry can be considered useful since it provides an attractive way for engineers to think out of the box and allows them to implement or reinforce common activities related to the process of their daily work. It was noticed that the busy engineers in the day-to-day operation created their own time to challenge themselves and propose some improvements in the current user process.

(c) *Lessons learned from the framework, model, and its software tool to assess the gamification strategy:* the assessment framework [2] provides a strong framework to evaluate the gamification strategy. Besides, the tool that supports the implementation of the method allows to get the scores automatically, however, as a disadvantage, we should highlight that this tool is available only in the Spanish language, and the participation of an expert must select some specific elements.

Finally, it is important to highlight that as future work in implementing gamification strategies in the automotive software development environment we have identified interesting topics as next listed:

1. To implement improvements in the current automotive gamification framework according to the results of the gamification assessment model, and then assess the new modified gamification framework using the same assessment model.
2. To tailor and customize the current assessment framework to have less expert dependence, and to calculate and provide scores more automatically. Besides, it can be improved to be more oriented according to the needs of the automotive environment and making it easy to implement for any automotive organization.

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