

Gamification and Evaluation of the Knowledge Management Application in a Software Quality Lab: An Experimental Study

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Abstract: This paper presents the application of Gamification, proposed by Alcantara and Oliveira (2018), for Teaching and Learning of Knowledge Management in a Software Quality Lab. The proposal is briefly presented, followed by the description of the application in the laboratory. Finally, we present the results obtained by a quantitative evaluation, based on the data collected during the experiment, followed by a qualitative evaluation based on the SWOT (Strength, Weakness, Opportunity and Threats) analysis from the perspective of the participants and, soon after, the final considerations are presented.

1 INTRODUCTION

Knowledge Management is of great importance within the competitive landscape for organizations. Knowledge is highlighted as a business asset raising the competitive capacity of the company, which has a set of balanced intellectual capital and, through the well-known Knowledge Management process, manages to generate and store this intangible asset (Aires et al., 2017). Dalkir (2005) argues that given the relevance of knowledge in all areas of life, including business, two aspects of knowledge are crucial to its viability and success at any level: Knowledge assets, which must be applied, fed, preserved and used as much as possible by individuals and organizations; and Processes related to knowledge to create, organize, transform, transfer, group, apply and preserve knowledge that must be intentionally managed in all areas of comprehension.

Even with knowledge having gained such importance, many organizations neglect or do not know how to manage this intellectual asset (Aires et al., 2017). Falcão et al. (2014) state that in the current generation it is necessary to use a teaching methodology that is more playful and involves the digital media, which are part of the student's daily life, with the contents taught in the classroom, providing an attractive environment, interactive and that better promotes learning.

Gamification appears with the purpose of stimulating the participants to a certain action,

assisting in the solution of problems and stimulating the learning process (Gonçalves et al., 2016; Freitas et al., 2016).

In addition to this introductory section, this paper is organized in the following sections: Section 2 presents the background about the subject of this paper, Section 3 presents some related works about this research, Section 4 presents briefly the Software Quality Lab where the knowledge management application was applied, Section 5 describes the gamification, Section 6 presents the evaluation of the gamification and Section 7 discusses the results obtained with the research and possible future work.

2 BACKGROUND

Oliveira (2018) classifies knowledge into two types: tacit and explicit. Tacit knowledge is that acquired with personal experiences and that is in the minds of individuals. It is difficult to share because it is an internalized knowledge in the individual. Explicit knowledge is one that can be represented in the form of data, stored in a knowledge base and communicable, so that other people have access.

According to Tabares et al. (2016), Knowledge Management is the way the human resources or machine learning share and acquire experiences from different sources. To have value within the organization, this knowledge needs to be managed

by a life cycle that encompasses the capture, storage, transformation, transfer, and distribution phases. Jurado et al. (2015) propose the use of Gamification as an alternative to improve participation in knowledge management processes.

Gamification consists of the use of game elements in real contexts. There are four basic characteristics that define a Game: **Goals**, which represent the goal to be achieved within the game, besides being the motivating factor for the player's involvement, **Rules**, which correspond to the restrictions, norms and limitations of the user within the game, **Feedback**, which is the response to the player when performing some task or action in the game informing and directing the user about the goal to be achieved, and **Voluntary Participation**, which represents the freedom of the player to perform or not a certain action or strategy within the game, as well as represent their initiative to play (Freitas et al 2016).

Chou (2015) classifies motivation into two types: **Extrinsic**, which is one that arises from an objective, purpose or reward, where the task itself is not necessarily interesting or attractive, however, due to the objective of the task or the reward attributed to who to comply with, people become motivated to do it, and **Intrinsic**, which is the motivation that people begin to have by performing the task itself, regardless of whether or not there is a reward for its accomplishment.

Costa and Marchiori (2016) affirm that the elements of games are classified in three categories: Dynamics, Mechanics and Components. These categories are related to each other, so that each Mechanics are related to one or more Dynamic(s), which in turn are related to one or more Component(s).

Dynamics constitute the highest level of abstraction, representing interactions between players and game mechanics (Werbach and Hunter, 2012).

Werbach and Hunter (2012) argue that Mechanics, in turn, are the basic processes that drive action and engages players. Each mechanic is a way to achieve one or more dynamics (Costa and Marchiori, 2016).

Components are applications that are used and visualized in the interface of the game and, like a Mechanics, connect to one or more Dynamics(s), where many components can constitute a Mechanics (Costa and Marchiori, 2016).

3 RELATED WORKS

Elm et al. (2016) present the software CLEVER, which proposes a game of trivia (questions) and RPG for dissemination of business knowledge. This game uses games elements and each battle is won with correct answers. One of the weaknesses is that the game does not include knowledge generators, an important person in knowledge management who produces new knowledge (assets) for the organization, and also does not define the experts to validate knowledge, since all knowledge generated must be analyzed by a expert in order to determine the efficiency and usefulness of a given knowledge. One point of improvement proposed as future work is an evaluation with a large number of participants to validate this game, design a repository of knowledge to store and maintain the management of all knowledge generated and useful to the organization, and integrate the game with that repository of knowledge.

Yin et al. (2016) present Light Quest, which proposes a game to increase motivation in the generation, dissemination and evaluation of knowledge. It is a game that stimulates the ability to produce, disseminate and absorb knowledge in the organizational environment, using Cards where knowledge is recorded and then evaluated and scored by another team. This score is used to increase the character level of the user who registered the knowledge. One of the weaknesses is that the evaluation of the Cards is made by people who may not be experts in that knowledge to be evaluated.

In this context, Alcantara and Oliveira (2018) present a Gamified proposal for Support to Teaching and Learning of Knowledge Management. Stimulating the process of generation, dissemination, capture, absorption and socialization of knowledge along different stages of a Gamification flow, contemplating the main characters of the Knowledge Management process, such as: the knowledge generators responsible for producing new assets for the organization, and the Expert, responsible for validating the knowledge produced.

4 THE GAME OF KNOWLEDGE MANAGEMENT

The Software Quality Lab, called SPIDER (<http://www.spider.ufpa.br>), has been established since 2008 at the Federal University of Pará from Brazil, and develops activities for research and

development of innovation for software development companies. The Lab has already trained more than 30 master’s students, 6 doctoral students and 50 scientific initiation students. The Lab has more than 150 scientific papers published in conferences and journals around the world. The Lab has already won many awards, among which stands out in 2012 the award for best research project evaluated by the Brazilian federal government.

The Software Quality Lab was the context of the case study that will be presented and had the following Research Question (QR): Does the use of gamification aid in the teaching and learning process of knowledge management?

In order to respond to this QR, a gamified scenario was created for this case study, which has the following elements: physical space (laboratory), the players (members of the laboratory), the judge (doctoral researcher), expert (professor), master student (researcher responsible for this work), and other used game elements, detailed in the following subsections.

4.1 Description of the Game

Alcantara and Oliveira (2018) propose a Gamification to Support the Teaching and Learning of the Knowledge Management assets and process, as can be seen in Figure 1.

It consists of eight steps (Start, Create Knowledge and / or Comments, Evaluate Cards, Identify Target Audience, Duel, Pack Card and Communicate Target Audience, Knowledge Repository and Ranking), being the last of feedback for users, stimulates the process of generating, disseminating, capturing, absorbing and socializing of the knowledge along different stages of the flow, contemplating the main characters of the Knowledge Management process: knowledge generators and the expert.



Figure 1: Gamification Flow.

The dynamics present in the Gamification proposal are: **Restrictions**, which represents constraints or forced compensation, **Emotions**, which are dynamic that arouse feelings of curiosity, competitiveness, frustration, happiness, among others, **Narrative**, which consists of a consistent and continuous plot, **Progression**, which represents the growth and development of the player, **Relationships**, which represents the social interactions that generate feelings of camaraderie, status, altruism, among others.

The mechanics used are: **Feedback**, represented by the activity, participation and final medals, described in (Alcantara and Oliveira, 2019), in addition to the Ranking stage, **Challenges**, which are composed of activities that must be performed at each stage of the flow, **Reward**, consisting of the Points and Bonus components, **Competition**, represented by the stages of the Duel and Ranking flow, in addition to the medal component, as a way to stimulate competition among the Players, **Cooperation**, present in the activity Consult Card in the Knowledge Repository stage, where the participants are motivated, through the activity, to consult the Cards of the other participants generating score for both the player that consulted, and the owner of the Card, and **Acquisition of Resources**, represented by the activities of Create Knowledge Card and Comment Card, in the Generate Knowledge Cards step (Alcantara and Oliveira, 2019).

Finally, we used some elements of games such as: **Superior Meaning**, where the user understands that he / she is performing an important activity for the organization, in addition to receiving a score for his / her growth in the Ranking, **Boss**, which is represented by a task that needs to be performed to advance to the next step of the flow, **Group activity**, which is represented by the sharing of knowledge through the Cards (socialization), in the Knowledge Repository, and by the possibility of creating teams to play, where each group represents an area of knowledge that are associated with each other (Alcantara and Oliveira, 2018).

The main details about Gamification and their characteristics and particularities, such as dynamics, mechanics, game components and motivations - Core Drives described in the framework Octalyziz by Chou (2015) - are presented in (Alcantara and Oliveira, 2018; Alcantara et al., 2018; Alcantara et al., 2019).

4.2 The Game Application

The players involved in the Gamification proposed by Alcantara and Oliveira (2018) are: the **Judge**, responsible collaborator for the development of the Class scores and feed the Gamification accompaniment worksheet; in the application of the gamification proposal in the lab only one participant acted with this profile, the **Player**, who is participating in Gamification generating, evaluating, disseminating and absorbing new knowledge; in the experiment performed in the lab five participants acted in this profile, the **Master**, researcher who coordinates the Gamification, responsible for defining the times in each activity and when to move to the next step of the flow; in the lab experiment one participant acted in this profile, and the **Expert**, expert member in the field of knowledge that is being studied; its function is to help in the resolution of doubts, to assign a score to the Cards created by the Players and to indicate the knowledge that will be stored in the knowledge repository and disseminated in the group; in the application of Gamification proposal in lab only one participant acted with this profile.

At the start of the Gamification flow, its functioning was explained, the scores defined for each stage, the rules that compose it and presented the Task List that would be performed in the current iteration, in order to encourage the generation and use of knowledge, besides being performed a simulated round for understanding. The Individual Tracking Form was also distributed to the Players and the Expert, where each Player should record the Cards Identifier created by him / her, the Card Identifier that were validated along with the note assigned to them, and the Target Audience suggestion (Alcantara and Oliveira, 2018).

After completing this stage, the gamified worksheet was completed according to the performance of each participant, as can be seen in Figure 2, obtaining the individual feedback regarding participation, performance of the activities and final medal, whose rules are described in (Alcantara et al., 2019).

Following the Gamification flow, the Create Knowledge and / or Comment Cards task starts. At this step the Player has the option to create a Card or comment one already made available in the Knowledge Repository (Alcantara e Oliveira, 2018).

In the Gamification application, participants completed the Cards made available with knowledge that they thought was important in the context of the project selected by the lab coordinator to be a topic

for knowledge generation. For this, it was necessary to fill in some identification data of the Card, as can be seen in Figure 3, such as: **Author**, filled in with the name of the participant, **Date**, filled in with the day, month and year of creation of the Card, **Identifier**, consisting of numeric digits where the first 2 digits represent the author's registration, and the remaining digits represent the sequential number of breeding Cards created by him / her, **New**, where the author signs with an "X" if the knowledge to be described is something new, or **Comment**, where the author signs with an "X" if the knowledge to be described is related to a Card of the "Knowledge Repository". In this case, it is also necessary to fill in the **Identifier** with the number (registration of the author who created the Card + sequential number of creation) of the Card to be commented, **From MY area of activity**, the author must indicate an "X" if the subject to be reported is related to his / her area of expertise or performance, if it is not in his / her area of work, the author should check the option **FROM OTHER area, Description Knowledge / Commentary**, where the author describes a unique knowledge or comment having as criteria the **relevance**, which represents the degree of importance of this knowledge, the **clarity**, which is how this knowledge is described, and the **attendance to the subject**, which represents the alignment, compliance and potential to solve a given problem or subject.

The remaining fields are filled by the Master if the Card is approved, the "Pack Card and Communicate Target Audience" step, with the exception of **queries** field, which is filled when creating a Card comment related to this card. The "**Grade**" field corresponds to the sum of the grades assigned by the Expert, to the knowledge created based on the relevance, clarity and attendance to the subject. The **Expert** field must be filled in with the name of the participant who has the Gamification Expert profile. The **Target Audience** field must be completed with the public to whom this knowledge is intended, identified by the Expert.

After the creation of the Card, each Player has taken note of their Individual Tracking Form, as can be seen in Figure 4, identifying all their created cards with their registration number and sequential creation number.

In the Evaluate Card step of the flow was evaluated the Comments and Cards generated by other users, and the Player can not evaluate the ones he / she created. Each Player, and the Expert, evaluated the Cards and Comments created in the current Gamification iteration, based on the criteria:

Start										Activity Medals				Participation Medals				Final Medal			
Players	Participate in the Simulated Round (10 of 10)	Presence (10 of 10)	Participation (10 of 10)	Suggestion (10 of 10)	Question (10 of 10)	Missing (-10)	Do not Activity (-3)	Disturb (-3)	BONS	Estrelas	Medal 1	Medal 2	Medal 3	Medal 4	Medal 5	Medal 6	Medal 7	Medal 8	Medal 9	Medal 10	
Participant 1	10	10	4	4	2				20	1											
Participant 2	10	10	6	4	6	10			16	1											
Participant 3	10	10	2	2	4				18	1											
Participant 4	10	10	4	2	4				20	1											
Participant 5	10	10	4	4	4				22	2											

Figure 2: Gamification Worksheet – Start step.

relevance, where it was evaluated whether the knowledge generated in the Card or the comment was important to the organization, scoring from zero to two, **clarity**, where it was evaluated if the information described in the Card or comment was understandable, scoring between zero and two, and **attendance to the subject**, where it was evaluated if the knowledge described in the Card or comment answered the proposed problem, punctuating between zero and six in this question, following the descriptions in (Alcantara and Oliveira, 2018).

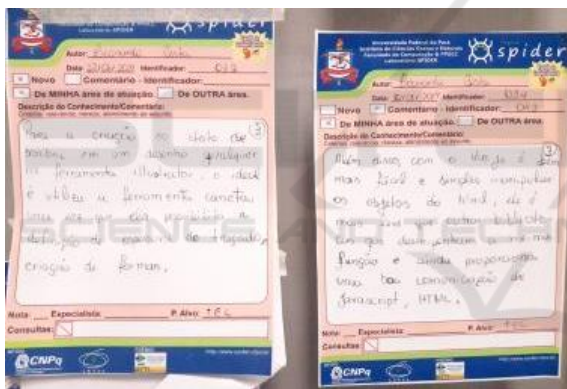


Figure 3: Knowledge Cards.

Following the Gamification flow, in the Identify Target Audience step, the Players and the Expert, after evaluating each Card or comment, identified a target audience, where this knowledge best applied.

FICHA INDIVIDUAL DE ACOMPANHAMENTO			
Nome: <i>Anderson Sales Furtado</i>		Função: <i>Player</i>	
CARDS CRIADOS			
Identificador	Tipo de Card		Pública-Alvo
	Novo	Comentário	
021	X		
022	X		
023	X	X	
024		X	
025		X	

Figure 4: Individual Tracking Form - Created Cards.

In the Duel step of the Gamification flow, the grades given for the same Card or comment by the Players and by the Expert in the Evaluate Cards step were compared, and the Player who had the evaluative grade equal to the grade given by the Expert was the winner of the Duel, receiving an extra score defined and disseminated by the Master at the beginning of the Gamification iteration, according to Alcantara and Oliveira (2018).

In the Pack Card and Communicate Target step of the Gamification flow, the Cards or Comments that obtained in the Evaluate Cards step the grade greater or equal to six in the Expert's evaluation, in addition to the points given in the criteria of relevance, clarity and attendance were fixed in the Knowledge Board, as can be seen in Figure 6, and the target public, identified by the Expert in the Identify Target Audience step, informed of the availability of this new knowledge for possible queries and comments.

The Knowledge Board, in Figure 5, was organized in such a way that in the upper part was identified the 7 types of knowledge that are: **Description of the process**, where the knowledge is exposed in a sequential and logical, **Case** that it describes a specific situation, **Lesson Learned**, which reports a learning of a particular case, **Idea**, which alludes to a suggestion of improvement or something innovative, **Doubt**, which describes a question or subject that needs an explanation, **Domain**, knowledge related to the area of expertise of who is generating the knowledge, and **Association Rule**, which represents the knowledge generated from observance of other facts, enabling a logical conclusion (Oliveira, 2018).

In the left part of the Knowledge Board, the Target Public was identified, so that the Cards were positioned according to the Knowledge Type and the Target Audience, making it easy for users to identify the Cards.

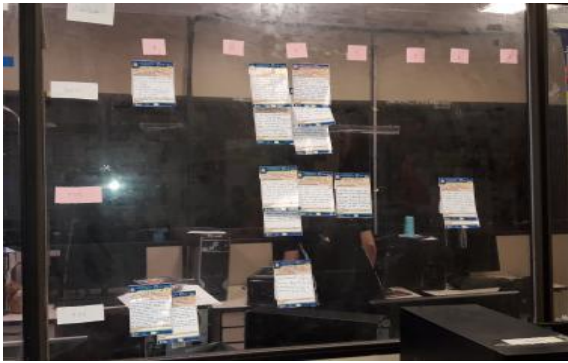


Figure 5: Knowledge Board.

In the Knowledge Repository step of the Gamification flow, Players had access to all approved Knowledge Cards and comments, which were made available in the Knowledge Board, and thus to identify possible areas where it is feasible to generate a new Card or create a comment related to a Card in the Knowledge Repository.

Finally, the Ranking step, where the Players identified their performance in relation to the other players in the amount of points reached throughout the gamification and through the average of the final medals. Finally, the general medal was presented that is attributed to each participant according to their performance in the activities of each step of the flow and their participation, as can be seen in Figure 6.

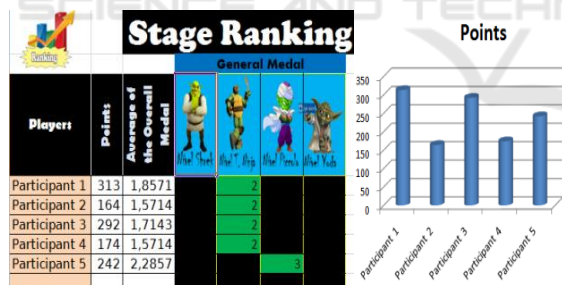


Figure 6: Ranking step.

5 THE EVALUATION

In order to evaluate the application of Gamification proposed by Alcantara and Oliveira (2018) in the lab, the Gamification Worksheet was used to analyze the performance of the Players in the main activities of each step, through the Activity Medals; the commitment throughout the flow (presence, doubts, suggestions, participation, faults, not to carry out the activities and disrupt the work), through the Participation Medals, as can be seen in Figure 2; the

Final Medals were also analyzed, resulting from the combination of Activity Medals and Participation Medals; and, finally, the General Medal.

5.1 Comparison between the Results Obtained

The quantitative data that were collected for the analysis of this case study are allocated in the Gamification worksheet, while the qualitative data were collected by audio and analyzed by the authors of the study.

5.1.1 Quantitative Results

Analyzing the Gamification Worksheet, in the Participation Medals question, we noticed 80% of the participants in the Ninja Turtle level and only 20% in the Piccolo level.

While in the Medal of Activities and Final Medals, along the step of the Gamification flow, the performance of the Players was analyzed, as shown below.

In the Start step, 100% of the participants reached Activity Medals of Yoda, which demonstrates their mastery over the activities proposed in this stage. To win this medal was necessary to perform the activity "Participate in the simulated round" which totaled 10 points. While in Final Medal, 80% of Players won the Ninja Turtle Medal, and 20% the Piccolo Medal.

Table 1 shows the range of points required for each Medal in Create Knowledge Cards and / or Comments, Evaluate Cards, Identify Target Audience, Duel, Pack Card and Communicate Target Audience, and Knowledge Repository steps.

Then, in the "Create Knowledge Cards and / or Comments" step, in the Activity Medals category, 80% of the Players achieved the Shrek Medal and only 20% of the Players the Ninja Turtle Medal. As for the Final Medal, 60% of the Players won the Shrek Medal and 40% the Ninja Trutle Medal.

In the Evaluate Cards step, in the Medals of Activity category, 20% of the Players reached the Shrek Medal, 60% of the Players reached the Ninja Turtle Medal, and only 20% of the Players the Piccolo Medal. In the Final Medal, 20% of the Players won the Shrek Medal, and 80% the Ninja Turtle Medal.

Next, in the Identify Target Audience step, in the Medals of Activity category, 20% of Players reached the Shrek Medal, 40% of Players reached the Ninja Turtle Medal, 20% of Players reached the Piccolo Medal, and only 20% of Players a Yoda Medal. In

the Final Medal question, 20% of the Players won the Shrek Medal, 40% the Ninja Turtle Medal, and 40% the Piccolo Medal.

Table 1: Score Range for Medal of Activities in Create Knowledge Cards and / or Comments, Evaluate Cards, Identify Target Audience, Duel, Pack Card and Communicate Target Audience, and Knowledge Repository steps.

Medal of Activity	Create Knowledge Cards and / or Comments, Evaluate Cards and Identify Target Audience	Duel	Pack Card and Communicate Target Audience	Knowledge Repository	Range of Points				
					Yoda	From 61	From 350	From 160	From 13
Piccolo	41 to 60	150 to 300	100 to 140	10 to 12					
Ninja Turtle	21 to 40	50 to 100	40 to 80	7 to 9					
Shrek	0 to 20	0 to 49	0 to 20	0 to 6					

In the Duel step, in the Medals of Activity category, 20% of the Players reached the Shrek Medal, 60% of the Players reached the Ninja Turtle Medal, and only 20% of the Players the Piccolo Medal. In the Final Medal question, 20% of the Players won the Shrek Medal, and 80% the Ninja Turtle Medal.

In the Pack Card and Communicate Target Audience step, in the Activity Medals question, 100% of the Players reached the Ninja Turtle Medal. In Final Medal, 100% of Players won the Ninja Turtle Medal.

In the Knowledge Repository step, in the Medals of Activity question, 100% of the Players reached the Shrek Medal. In the Final Medal, 80% of the Players won the Shrek Medal, and 20% the Ninja Turtle Medal.

Finally, in the Ranking step, the scores of each participant were presented along with the General Medal of each one, as can be seen in Figure 7, where 80% of the participants obtained the General Medal of Ninja Turtle, and only 20% the Piccolo Medal. Table 2 shows the range of points required for each Medal in this step.

Table 2: Value intervals for General Medal.

Arithmetic Average of Final Medals		General Medal
3,1 to 4	=	Yoda
2,1 to 3	=	Piccolo
1,1 to 2	=	Ninja Turtle
0 to 1	=	Shrek

5.1.2 Qualitative Results

The qualitative results were collected from interviews in the feedback meeting with all Gamification participants. Dynamics, generated products, flow, Gamification (elements and mechanics), and roles (actors) were analyzed.

In relation to the Dynamics present in the Gamification, the social interaction, promoted by the dynamics, the possession aspect, the almost instantaneous feedback and the exchange of knowledge were presented as strengths. As Opportunities the participants pointed out the possibility of using a public worksheet for better monitoring by all stakeholders along the dynamics or a tool that enables instant feedback. As weaknesses, still in relation to the dynamics, they punctuated the absence of playful terms and narrative, characteristic of most games. And, as a threat, they punctuated the amount of participants that can compromise the follow-up of the process, and the execution time of each step that may detract from the outcome.

In the Generated Products criterion were presented as strengths the Tracking Form, which enabled participants to control the knowledge cards that allowed interpretation in a clear and intuitive way and the use of the lab environment. As Opportunities the participants scored the possibility of Level Creation progression for the products. As weaknesses they pointed out the absence of the fields with the types of knowledge in the Cards. And, as a threat, they punctuated the possibility of excess Cards which can create bottlenecks, especially in the Evaluate Cards step.

Regarding the Flow were presented as strengths the Visual Representation of the Gamification, which makes it possible to visualize the whole flow. As Opportunities the participants pointed out the possibility of improving the Duel activity. As weaknesses they pointed to the absence of a pre-established target audience list, which could become a disincentive factor for participants.

In the Gamification criterion, almost instant feedback was presented as strengths. As

Opportunities participants pointed out the possibility of an award at the end of the experiment, the possibility of a reward based on the grade given by the expert for each Card and the use of a software in the gamification that allows greater agility in the creation of Cards and generate feedback snapshot. As weaknesses they pointed out the existence of many rules and a weak feeling of play, necessitating something more playful. And, as a threat, they punctuated the limitation of tasks.

Finally, in relation to the Roles (actors) were presented as strengths the fact of the roles being well defined and clear, helping in the identification of each actor. And, as a threat, they punctuated the number of players that, if there are many, can demand a greater number of participants in both the Judge profile and the Expert profile.

6 CONCLUSION

This paper presented the results of a case study that allowed improving the teaching and learning techniques of Knowledge Management. The results obtained with the Gamification worksheet and feedback from the participants enable the QR response that was presented in Section 5, where the use of gamification as a tool to support teaching and learning of knowledge management contributes positively.

As future works, the authors suggest the use of the Gamification proposal in scenarios of different professional contexts, in order to ascertain the suitability of Alcantara and Oliveira (2018) proposal in different scenarios; the application of the proposal with a more expressive number of participants; and the use of the proposal in the classroom.

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