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Gamification in software engineering – A systematic mapping

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ABSTRACT

Context: Gamification seeks for improvement of the user's engagement, motivation, and performance when carrying out a certain task, by means of incorporating game mechanics and elements, thus making that task more attractive. Much research work has studied the application of gamification in software engineering for increasing the engagement and results of developers.
Objective: The objective of this paper is to carry out a systematic mapping of the field of gamification in software engineering in an attempt to characterize the state of the art of this field identifying gaps and opportunities for further research.
Method: We carried out a systematic mapping with a view to finding the primary studies in the existing literature, which were later classified and analyzed according to four criteria: the software process area addressed, the gamification elements used, the type of research method followed, and the type of forum in which they were published. A subjective evaluation of the studies was also carried out to evaluate them in terms of methodology, empirical evidence, integration with the organization, and replicability.
Results: As a result of the systematic mapping we found 29 primary studies, published between January 2011 and June 2014. Most of them focus on software development, and to a lesser extent, requirements, project management, and other support areas. In the main, they consider very simple gamification mechanics such as points and badges, and few provide empirical evidence of the impact of gamification.
Conclusions: Existing research in the field is quite preliminary, and more research effort analyzing the impact of gamification in SE would be needed. Future research work should look at other game mechanics in addition to the basic ones and should tackle software process areas that have not been fully studied, such as requirements, project management, maintenance, or testing. Most studies share a lack of methodological support that would make their proposals replicable in other settings. The integration of gamification with an organization's existing tools is also an important challenge that needs to be taken up in this field.

Contents

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1. Introduction

The field of gamification has experienced significant growth and popularity in the last few years [1–4]. Although many definitions can be found in the literature, gamification has been defined in [1] as "the use of game design elements in non-game contexts". Gamification uses the philosophy, elements, and mechanics of game design in non-game environments to induce certain behavior in people, as well as to improve their motivation and engagement in a particular task. That is to say, gamification takes those features that make real games fun and attractive (and even addictive), and uses them to improve the player experience in a non-game environment, such as the workplace, the school, a software application, or customer-oriented web site.

Gamification has been applied in many different domains in the last years. One of those domains is education and training [5], where game elements are used to increase the motivation, engagement and performance of the students. Gamification has also been a central part of the design of many mobile applications for smartphones and tablets, in the quest to achieve stronger user engagement and diffusion of the applications. Corporate websites oriented toward customers have also been the object of gamification as they seek to improve the customer experience on the website [6]. Gamification has also been applied in corporate environments in an attempt to improve the results of employees in the development of their daily tasks and work [7].

This paper focuses on the potential benefits gamification can bring to the Software Engineering (SE) field; its application here deserves special attention, given the human-intensive nature of software processes. This turns gamification into a promising field which can help to improve the daily engagement and motivation of software engineers in their tasks. As a matter of fact, some existing commercial tools which support SE processes are starting to incorporate basic gamification mechanisms; see, for instance, JIRA Hero [8], RedCritter [9], PropsToYou [10], ScrumKnowsy [11], MasterBranch [12] or Visual Studio Achievements [13]. In the SE field, therefore, researchers and practitioners are not unaware of the potential benefits of gamification in the workplace. A number of proposals have been published in recent years, some of them focused on teaching and training, others on real SE contexts.

Bearing in mind the aforementioned ideas, the focus of this work is to analyze the application of gamification in Software Engineering (SE); a systematic mapping has been carried out to that end. The aim is to provide a more structured view of the state of the art in the field and to identify existing gaps and weaknesses. The scope of this systematic mapping is the software development context; it does not include those pieces of work focusing on teaching or training. The rest of the paper is structured as follows: Section 2 presents the related work. Section 3 describes how systematic mapping was planned. In Section 4 we present the results we obtained during the study, providing answers for the stated research questions. The discussion of the results obtained in the study is set out in Section 5 and finally, Section 6 summarizes the conclusions of the paper and outlines challenges that may lead to future research.

2. Related work

To the best of our knowledge, in the relevant literature there are no systematic literature reviews (SLR) or systematic mapping studies which tackle the application of gamification in SE. It is true, however, that we can find some work whose aim is to provide the state of art in the field of gamification. In this line, Hamari et al. [14] analyze the empirical studies on gamification by means of a literature review of peer-reviewed papers, the aim of whose main research question is to evaluate the usefulness of gamification. The results are classified according to a framework which considers: (1) motivational affordances, (2) psychological outcomes, and (3) further behavioral outcomes. As a result of the review, authors conclude that gamification does work, "but some caveats exist". Most papers report positive results from gamification, with some empirical evidence. However, some underlying confounding factors exist in the empirical results; these consist mainly of the role of the context being gamified and the qualities of the users. Methodological improvement is proposed for future research and suggestions are given for avoiding the pitfalls of current studies. Xu [15] conducts a literature review about gamification in web applications. The author concludes that the current state of gamification focuses on the relatively superficial game mechanics (point, level, leaderboard and badges). As a future direction for research to consider he highlights: social interaction; mobility, by supporting the ubiquitousness of mobile devices and; analytics which must be enhanced, although most of the commercial tools already include some engagement metrics and behavior analytics.

On the other hand, we can find some systematic literature reviews (SLR) in the related area of serious games. In particular, Connolly et al. [16] analyze the potential positive impacts of serious games and computer games on gaming users from 14 years old, with respect to learning, skill enhancement and engagement. The study selected 129 papers out of 7392, which include some empirical evidence. In addition, a multidimensional approach was developed to categorize the games. The main conclusions from this study were the reported diversity found in the research on the impact of playing digital games, and the difficulties of classifying learning outcomes. Some evidence about the effectiveness of games-based learning was also collected, although it is suggested that more rigorous research is needed. Another significant observation is that to incorporate games in learning environments it is essential to develop a better understanding of the tasks, activities, skills and operations that different kinds of games can offer and examine how these might match desired learning outcomes. Steinkuehler [17] describes the qualitative results obtained about the analysis of massively multiplayer online games applied for learning. The results are obtained from a two and a half year cognitive ethnography of the MMO Lineage and demonstrate the core practices that constitute gameplay in virtual worlds. They focus on the development of educational activities for after-school clubs that capitalize on those capacities. Other reviews look at the application of games in other domains. Graafland et al. [18], for instance, tackle the application of digital games for training medical professionals. 25

Articles were identified as a result, describing a total of 30 serious games, 17 of which were classified as games for specific educational purposes and 13 as commercial games for developing skills relevant to medical personnel. Six serious games had some supporting empirical evidence. The authors conclude that blended and interactive learning by means of serious games is promising and applicable for training, both in technical and non-technical skills that are relevant to the surgical field. More validation is required, however, before these games are integrated into surgical teaching curricula.

3. Planning of the systematic mapping

The purpose of this study is to determine and characterize the state of the art of gamification in software engineering, analyzing the existing proposals and research work and thus identifying potential gaps and opportunities for future research. The main research question guiding this study is therefore:

What is the state of the art of Gamification applied to Software Engineering?

To carry out this systematic mapping, we followed the recommendations in [19,20]. In this section we present the planning of each step of the study: research questions, data sources and search strategy, along with the classification and evaluation criteria.

3.1. Research methods and questions

The research questions we established for this study attempt to provide specific insight into the relevant aspects of the existing proposals in gamification applied to software engineering. These include questions about which particular software engineering process areas have been the object of gamification, as well as about which game elements or mechanics have been used in existing work. We also wanted to analyze the type of research carried out up to that time (theoretical, proposal, empirical), together with the type of research forums in which these works have been published and presented. The research questions of this systematic mapping study are described in Table 1.

Table 1
Research questions of the study.

Nr.	Research question
RQ1	What software engineering processes have been the object of gamification?
RQ2	What gamification elements have been used in existing work on software engineering gamification?
RQ3	What research methods have been used in research into software gamification quality evaluation?
RQ4	What types of publications or forums have dealt with the issue of software engineering gamification?

Table 2
Search string.

Major terms	Alternative terms
Gamification	(gamification OR gamifying OR gamify OR funware) AND
Software Engineering	((software engineering) OR (software process) OR (software requirements) OR (software testing) OR (project planning) OR (project assessment) OR (software risk) OR (software configuration) OR (software design) OR (software construction) OR (software implementation) OR (software integration) OR (software maintenance) OR (software verification) OR (software validation) OR (software metrics))

Table 3
Summary of the search strategy.

Search strategy	
Academic databases searched	• Scopus • Science@Direct (subject Computer Science) • Wiley InterScience (subject Computer Science) • IEEExplore • ACM Digital Library • Springer Database
Other data sources	• Google (only non-academic sources)
Target items	• Journal papers • Workshop papers • Conference papers • Industry/professional workshop contributions • Industry/professional conference contributions • Non-academic online publications
Search applied to	• Title • Abstract • Keywords
Language	• Papers written in English
Publication period	• Until June 2014

3.2. Data sources and search strategy

To build the search string we chose two major search terms: "Gamification" and "Software Engineering". In the case of the second major search term, this was refined into a string considering the software processes defined in the ISO/IEC 12207 standard. The final search string we used in the study is shown in Table 2. The search terms were constructed using steps described in [21], in which Boolean OR is used to incorporate alternative spellings, synonyms or related terms (called "alternative terms"), and Boolean AND is employed to link the major terms.

The search strategy is outlined in Table 3. The scope of the search considers publications and contributions presented in both academic and professional forums and publications. That is, we have considered academic publications (such as those published in journals or presented in academic conferences and workshops) in addition to publications and contributions presented in industry or professional forums, such as conferences, workshops, and online publications. The search will also be recursive, that is, studies referenced in the primary studies will also be explored. Personal blogs or web pages have been excluded from the search.

In order to include non-academic publications and contributions in the study, it was necessary to make use of a general search engine, and that specifically used in this systematic mapping was Google. However, this led to some challenges, and it was therefore necessary to establish certain criteria during the use of this data source. The potential number of results returned by a general search engine can be very large (in the order of hundreds of thousands). In order to keep the search within reasonable bounds, we limited the number of results from Google that we explored to 300 (during the search we noticed that this number was

sufficiently high, since a significant part of the last results returned by the engine did not include any primary studies). What is more, this data source was used only to search for non-academic primary studies: those papers or articles published in industry/professional conferences, workshops, online journals/magazines or corporate blogs. As shown in Table 4, we excluded contributions published in personal blogs or web pages, or in product brochures.

Moreover, the search for primary studies was recursive. That is, once a primary study had been identified in one of the data sources, the references of that primary study were recursively explored by following the same search criteria.

The study excluded those papers that met some of the following criteria: research which does not treat software engineering gamification (but is rather research on the use of software engineering for gamifying other domains), serious games, or duplicate papers of the same research in different databases, papers available only in the form of abstracts or PowerPoint presentations and articles which present workshop abstract submission. We included studies on gamification in software engineering with experiences in academic environments, but we excluded those studies in which the primary objective is merely to gamify education. The selection strategy is summarized in Table 4.

3.3. Classification

To classify the studies found during the study, we established four classification categories, corresponding to each of the research questions of the systematic mapping. More specifically, the categories of dimensions in the classification scheme were:

1. *Software process:* To classify the studies in terms of the software engineering processes that have been the object of gamification, we first considered any software process defined in the ISO 12007 standard. However, after a first review of the primary studies we also identified other processes that are not explicitly present in ISO 12207, such as collaboration or knowledge management, which we included in the classification. For each paper, we discovered which software processes were the target of gamification. More specifically, if the purpose of gamification is to increase the motivation and performance of people participating in software engineering activities, we identified which activities are involved in the activities of those people in the gamified environment. Please note that gamifying an activity such as software implementation may contribute to the goals of other activities such as project management. However, in this classification we focused on the activities the participants are working on in the gamified environment. Note that, in many cases, more than one software process was considered by the primary study. This field is related to RQ1.
2. *Gamification element:* This could be point systems, badges, leader boards, rankings, etc. Since there is no clear and commonly-accepted taxonomy of the gamification elements and mechanics, we identified those applied in software engineering as we examined the studies we had found. This field is related to RQ2.
3. *Research method:* The research approach used was in accord with the classification system proposed by [22]. This could be evaluation research, proposal of solution, validation research (experiment, quasi-experiment, and case study), philosophical paper, opinion papers, and personal experience papers. This field is related to RQ3.
4. *Type of publication:* This field is related to RQ4 and could be journals, conferences, workshops, or others which include online publications or corporate blogs.

Table 4
Summary of the selection strategy.

Inclusion/exclusion criteria	
Inclusion criteria	• Terms fulfill the search string • Academic journal, conference and workshop papers • Contributions to industry/professional conferences, workshops, and online publications • Papers written in English • Publication date: until June 2014
Exclusion criteria for titles and abstract	• Papers which do not focus on software engineering gamification • Papers available only in the form of abstracts or PowerPoint presentations • Personal blogs or web pages • Product brochures
Exclusion criteria for full text	• Software engineering has been used to gamify other domains • Papers presenting a summary of a workshop

3.4. Evaluation

In order to provide a quality assessment of the studies chosen, a five-point Likert-scale questionnaire was designed. The questionnaire contained five subjective closed-questions. The possible answers to these questions show the reviewer's level of agreement, and range between "I do not agree (0)" and "I totally agree (5)". The authors set up a focus group for the evaluation of the primary studies, signifying that the assessment of each evaluation question for each paper was obtained by consensus. The final numerical value which generates the evaluation of each paper can be a value of between 0 and 5. The evaluation provides us with an insight into the degree to which different aspects of gamification are considered in existing research in the field. It was decided that as quality criteria for the selection of primary studies, the results of this assessment would help to identify the quality of research carried out, but that they would not be used to exclude articles from this systematic mapping.

The questions composing the quality assessment questionnaire are shown in Table 5. The purpose of these evaluation questions was to assess the primary studies in aspects such as the methodology they followed, as well as how their proposal is integrated with an organization's tool infrastructure. They also evaluated the evidence provided by the studies about impact on user engagement and performance, and to what degree their proposals could be replicated in other organizations/settings.

4. Results of the systematic mapping

4.1. Results of the search

The search process was carried out by following the criteria and strategies described in the previous section. Fig. 1 shows a

Table 5
Evaluation questions.

Nr.	Evaluation question
EQ1	Does the study follow a systematic methodology for gamification that can be applied in another setting?
EQ2	Is the proposal of the study successfully integrated with the tool ecosystem of the organization?
EQ3	Does the study provide evidence showing that gamification had a positive impact on user engagement and motivation?
EQ4	Does the study provide evidence showing that gamification had a positive impact on performance?
EQ5	Does the study present a proposal that can be replicated in other organizations/settings?

summary of the number of papers obtained in each step of the search process. As the results show, the number of primary studies obtained may appear to be quite small – there are just 16. However, as will be shown in greater detail in this section, all these papers were published between the years 2011 and 2013. The full list of primary studies gathered is listed in Appendix A.

Fig. 2 shows the distribution of the studies according to the year they were published. The first primary studies focusing on gamification applied to SE date back to 2011. The number of studies published in 2012 is twice that of 2011, and the number was smaller in 2013 than in 2012. However, the number of primary studies published in the first half of 2014 already exceeds the number of papers published in 2013. This result seems to follow the trend of general gamification (that is, gamification applied not only to SE). According to [3], the first use of gamification as it is nowadays understood happened in the year 2003. We also note that, according to [1], the first documented use of the term "gamification" dates back to 2008; since 2010 it has been gaining popularity significantly.

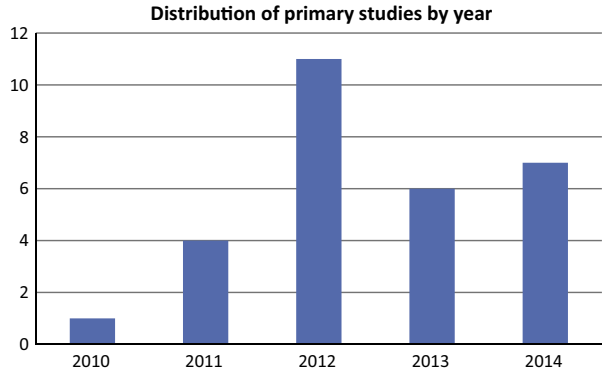

Fig. 2. Distribution of primary studies by year.

4.2. Research questions

In this section an analysis is performed of the primary studies obtained following the classification criteria and research questions that have been outlined previously. The answers to the stated research questions, according to the analysis performed on the primary studies selected are as follows:

4.2.1. RQ1. What particular software engineering processes have been objects of gamification?

The first parameter we considered in the classification of the primary studies was the process area or areas they address. In order to be able to work with a generally accepted group of process areas, we took those in the ISO/IEC 12207 standard. After carrying out a first classification of the primary studies with respect to RQ1, we decided to include two more process areas that are not considered explicitly by ISO/IEC 12207 in the classification, namely process improvement, knowledge management and collaboration. The reason is that, although they are not a specific ISO/IEC 12207 process, we believed they are significant for the SE community and are in fact taken into account by other generally-accepted models and standards, such as CMMI or the PMBOK.

The distribution of the primary studies in terms of the process areas they consider are shown in Fig. 3. Table 6 provides details of which process areas were considered by each of the primary studies. Notice that a particular primary study may consider more than one process area, and therefore the sum of the distributions shown in Fig. 3 is greater than the number of primary studies we found. We should also highlight that some primary studies did not focus on any particular software process area, so these studies have not been taken into account in these classification criteria. For example, [A19] presents a general view of the HALO software engineering environment, but does not give details about how it is applied to a specific SE process area.

Since the number of primary studies we found is relatively small, many of these categories have been considered in just one primary study. Fig. 4 provides an aggregated graph derived from this classification, in which the process areas that appear in the studies are grouped into five main blocks, namely project management (containing the areas of project planning and project assessment and control), software requirements (stakeholder requirements definition, system requirements definition, software requirements analysis), software development (software implementation), software testing (software testing and verification), and support processes (process improvement, problem resolution, knowledge management, and configuration management). The purpose of this figure is to provide a more global perspective of the distribution of the primary studies by process area, since most of the process areas shown in Fig. 3 have been considered in just one or two primary studies. It therefore provides us with an insight into which of the main topics in software engineering have been the focus of primary studies.

During the analysis of the primary studies, we did not find any that consider a software process that is different to those we have established for the classification. In all of them, the target audience of the gamified environment is the team of people involved in a software project. In the study of the primary studies we did not find any further distinction of different team roles targeted by the gamification.

As we can see in the results of this classification, software requirements, software development and software testing are the areas that attracted the greatest interest in the field of gamification

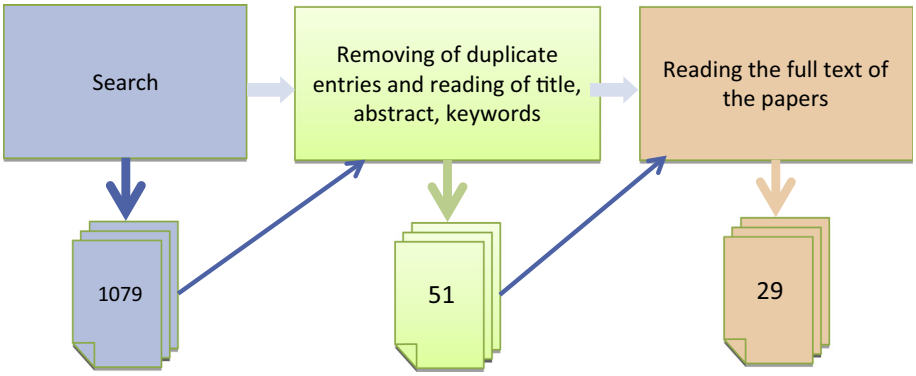

Fig. 1. Results obtained from the search process.

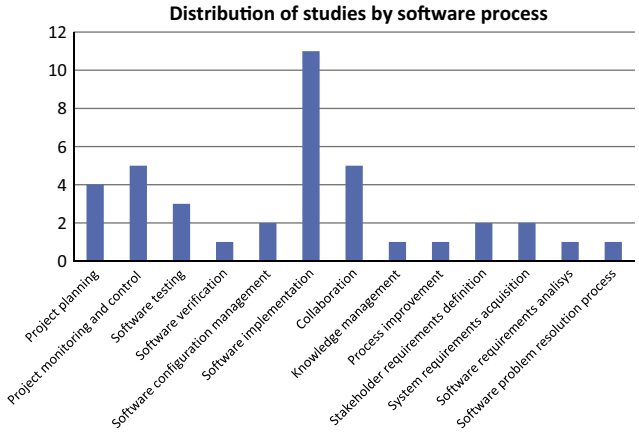

Fig. 3. Distribution of primary studies by process area.

Table 6
Process areas considered by each primary study.

Area	Studies
Project planning	[A1], [A2], [A13], [A14], [A15]
Project assessment and control	[A1], [A2], [A13], [A14], [A15]
Stakeholder requirements elicitation	[A7], [A9]
System requirements acquisition	[A7], [A9]
SW requirements analysis	[A7]
System implementation	[A4], [A8], [A11], [A15], [A16], [A17], [A22], [A23], [A24], [A27], [A29]
SE testing	[A3], [A8], [A12]
SW configuration management	[A4], [A20]
SW verification	[A3]
Process improvement	[A6]
Knowledge management	[A5]
SW problem resolution	[A10]
Collaboration	[A4], [A17], [A18], [A25], [A26], [A28]

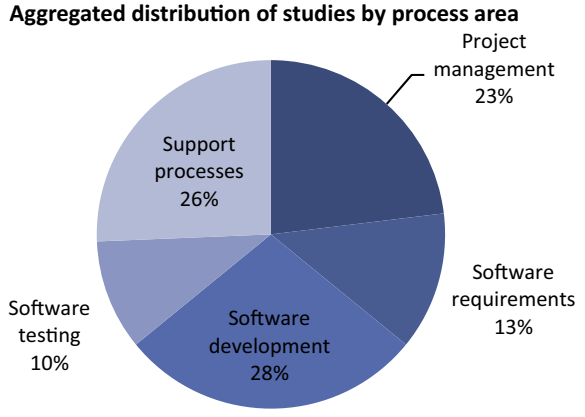

Fig. 4. Summary of study distribution by process area.

in SE, followed by project management and other support areas such as software configuration management. This result is not surprising, in our view, since software requirements, development, and testing all share features that make them suitable for the application of gamification. These characteristics include their level of difficulty in comparison with other tasks such as configuration management and the need for intensive collaboration among different players. They may even be tedious, in the case of software development and testing. Features like these make these types of activity a clear target for gamification, since it could help make these activities more fun and more attractive. Gamification enables collaboration and competitiveness among the different players to be fostered and encouraged, thereby enhancing their performance.

Regarding software requirements, the proposals of [A7] and [A9] make use of gamification to overcome well-known problems of software requirements elicitation and analysis, such as the lack of user involvement [23]. Their proposals place an emphasis on improving and motivating user participation and collaboration in requirements elicitation and analysis. In [A7], a collaborative environment for requirements elicitation is proposed, making use of gamification elements such as voting and rankings. The results of the evaluation of this proposal tell us that it made for better involvement and participation of stakeholders, as well as for better understanding of requirements. In [A9], a collaborative requirements elicitation environment is proposed, in which a point-based system is used to reward the participants for carrying out actions such as registering a new requirement, scoring an existing requirement, or commenting on requirements so as to clarify their meaning for all stakeholders. The evaluation of this proposal also reports improved user participation and motivation.

Only one of the primary studies we found focuses on SE activities related to project management, assessment and control. The primary study [A2] discusses task effort estimation and control, and proposes a model in which both the project manager and the worker in charge of completing a task are rewarded (with a point-based system) depending on their estimations for each task and the real result obtained after their completion. Primary study [A1] addresses the integral gamification of a project management system, incorporating gamification elements and techniques to an existing project management tool. This study also provides data regarding the evaluation of the success of this system. Primary studies [A13] and [A14] follow a similar approach to design a tool named *TaskVille* in which team members can see the progress of the project in a game-like visual interface.

System implementation is the process area that has been considered most in the primary studies we have found. In [A8], a general proposal for the gamification of software development activities was proposed. This study also reports results from a preliminary study in which outputs from the SonarQube [24] code quality platform were the basis for rewarding the developers. Latoza et al. [A12] consider the idea of incorporating gamification mechanics in a crowd development scenario. Passos et al. [A15] propose a gamified environment in which concepts of an iterative software development process are mapped to the various particular concepts of a gamified environment. For example, the different releases of the software product under construction correspond to the levels of the game, and the particular iterations that build each release are mapped to the different quests that make up a particular level of the game. Singer et al. [A20] focus on the impact of mutual assessment in collaboration-oriented environments for programmers. Snipes et al. [A23] suggest a game-like system to motivate the adoption of efficient work patterns for developers, in which they are rewarded as they adopt certain development practices. de Melo et al. [A4] automatically extract information from version control systems and analyzes the changes introduced by each developer in order to reward the more productive team members. Januszevski [A11] addresses the introduction of gamification elements in the Visual Studio platform. Primary studies such as [A16], [A17], and [A18] also consider the problem of rewarding team members that produce high quality contributions to the development of the system.

Bell et al. [A3] put forward a system in which software testing is presented as a series of quests the users have to complete. The proposals presented in studies such as [A8] and [A12] looked at testing in addition to development.

Other process areas have also been considered in the existing research on gamification applied to SE. Dencheva et al. [A5] propose improving contribution and participation in knowledge management in a corporate Wiki by incorporating game elements that affect a participant's reputation. Dorling and McCaffery [A6] discuss the idea of using gamification as a tool to foster transformational change and process improvement. Grant and Betts [A10] analyze how gamification has an impact on problem resolution in software development, focusing on the particular case of the well-known site StackOverflow [25]. Singer and Schneider [A21] used gamification to motivate more frequent commits.

A conclusion we can reach from the result of this first classification is that existing primary studies have left out some important process areas, such as the case of software maintenance, risk management, architectural design, or software validation, for example, all of which involve different types of players that must collaborate really well if they are to complete these tasks successfully.

4.2.2. RQ2. What gamification elements have been used in existing works on software engineering gamification?

The second aspect we considered in the classification of the primary studies was the gamification elements or mechanics they applied. We found no generally-accepted taxonomy of these mechanics, so made a list of gamification elements and mechanics from general gamification articles (such as [3,26,27]), and a preliminary review of the existing literature on gamification (not only the works which focused on applying it to software engineering). The gamification elements and mechanics found in the primary studies were:

- *Awards:* a particular award is given to the player on the completion of a behavior.
- *Point-based reward system:* the players obtain a reward in the form of points on the completion of a certain behavior.
- *Badges:* they represent certain achievements of the user.
- *Levels:* related to the point-based rewards; the users have a level that increases as they reach a certain number of points.
- *Quests:* the tasks the player has to complete are presented as a quest, with additional game elements (such a story) that makes it more attractive.
- *Voting:* players can vote on another player's behavior. The votes themselves represent the rewards obtained by each player.
- *Ranking:* a ranking with the top players is presented to all players to increase competitiveness. The position in the ranking can be defined by points, levels, or number of votes, for example.
- *Betting:* users bet on a certain event, such as an estimation, for example. The winner of the bet receives some reward in exchange.

Notice that some primary studies do not use the same name we do for each gamification element. We have identified those cases and classified the primary studies under one or several of the categories we have listed.

Fig. 5 shows the results of this classification. As we can see in this graph, points are by far the most widely-used gamification element, followed by badges and voting systems. This result follows the trend in gamification applications in other domains (such as mobile applications, or customer-oriented websites, for example), in which point-based systems, badges, and voting are the game elements used most. Table 7 shows details of which gamification elements and mechanics were used in each paper.

4.2.3. RQ3. What research methods have been used in research on software gamification quality evaluation?

Fig. 6 shows the distribution of the primary studies according to the research method they followed. Table 8 shows the details of each primary study. The results of this classification show that more than half the primary studies are either philosophical papers, or proposals of solutions that have no experimental evaluation or validation.

Most of the primary studies we have found, therefore, present some type of proposal on the use of gamification applied to software engineering, but do not apply it in a real scenario in order to validate the contribution and appropriateness of such a proposal.

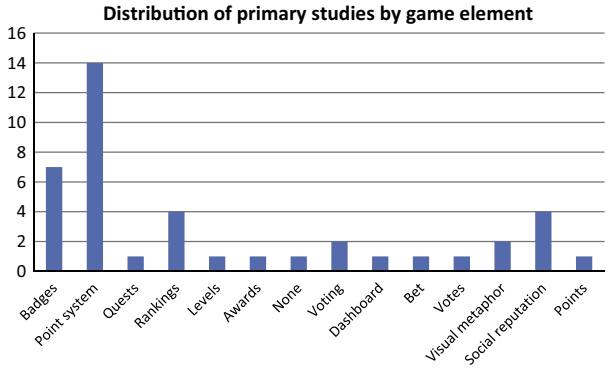

Fig. 5. Distribution of primary studies by gamification element.

Table 7
Distribution of primary studies by gamification element.

Area	Studies
Awards	[A5]
Point-based reward system	[A2], [A4], [A5], [A8], [A9], [A15], [A17], [A18], [A19], [A20], [A21], [A23], [A24], [A25], [A26]
Badges	[A1], [A10], [A11], [A15], [A19], [A23], [A26]
Levels	[A5], [A24]
Quests	[A3]
Voting	[A7], [A9], [A12]
Dashboard	[A7]
Betting	[A12]
Rankings	[A1], [A4], [A11], [A24]
Visual metaphor	[A13], [A14]
Social reputation	[A17], [A18], [A21], [A22]

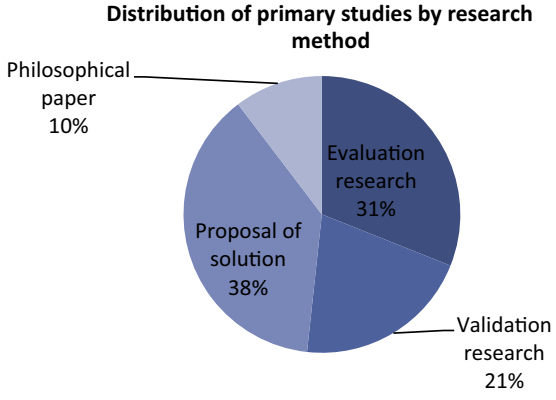

Fig. 6. Distribution of primary studies by research method.

Table 8
Distribution of primary studies by research method.

Area	Studies
Evaluation research	[A1], [A9], [A15], [A17], [A18], [A22], [A24], [A26], [A29]
Validation research	[A2], [A5], [A7], [A8], [A10], [A14]
Proposal of solution	[A3], [A4], [A11], [A12], [A13], [A16], [A19], [A20], [A21], [A23], [A25]
Philosophical paper	[A6], [A27], [A28]

4.2.4. RQ4. What types of publications or forums publish on software engineering gamification?

Fig. 7 shows the distribution of primary studies by the type of forum in which they have been published. Table 9 shows the primary studies for each type of forum. The classification shows that 93% of them were published as conference or workshop papers; only 7% of them were more complete papers published in journals. This indicates that most of the research in the field is still quite preliminary.

Fig. 8 shows a bubble graph summarizing the main results of the classification. The main dimension of the graph corresponds to the process area considered by the primary studies. The area to the left of this vertical axis shows, for each process area, the number of papers that used a particular gamification element. The area to the right of the vertical axis shows the number of papers in each type of work, for each process area.

Although the overall numbers may not be very significant, due to the small number of primary studies found, the highest percentage is that of papers using point-based systems as a reward for software development activities.

4.3. Evaluation

The last step of the analysis of the primary studies was the subjective evaluation of those elements that we considered relevant for a research work on gamification applied to SE. The research questions we posed for this evaluation are listed in Section 3. As explained in the planning of the systematic mapping, the questions focused on the methodology used in the primary study, the level of integration with the organization's tool ecosystem, experimental results showing improvement in user motivation and engagement, experimental results showing improvement in performance, and the degree to which the proposal can be replicated in other organizations. As explained in the section devoted to planning, the authors of the systematic mapping carried out the evaluation by forming a focus group. The score for each primary study in each of the questions was therefore obtained by consensus.

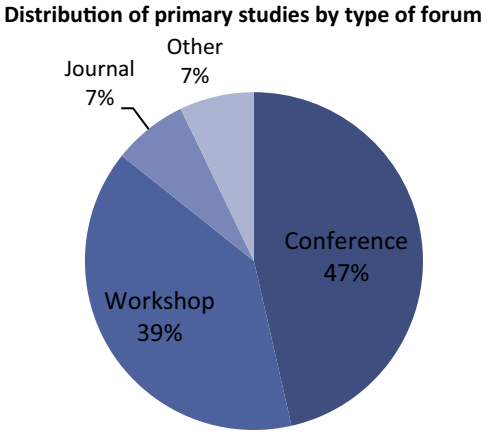

Fig. 7. Distribution of primary studies by type of forum.

Table 9
Distribution of primary studies by type of forum.

Area	Studies
Journal	[A6], [A9]
Conference	[A1], [A2], [A4], [A5], [A7], [A8], [A10], [A21], [A22], [A23], [A24], [A26], [A28], [A29]
Workshop	[A3], [A12], [A13], [A14], [A15], [A16], [A17], [A18], [A19], [A20], [A25]
Other	[A11], [A27]

Table 10 shows the results obtained in the subjective evaluation. The table shows the average and standard deviation for each question. Fig. 8 shows the distribution of scores for each evaluation question, that is, the percentage of studies that obtained each score for a given evaluation question. We do not set out the particular results for each of the primary studies, since a separate subjective evaluation of each of them is beyond the scope of this systematic mapping.

As the results shown in Table 10 show, the group of studies we analyzed is below 2.5 in two parameters, namely providing evidence of the effect of gamification on user motivation and performance. The main reason for this result is that few primary studies carried out experimentation to evaluate these parameters. The case of performance improvement is even more difficult, since an appropriate evaluation of this aspect should compare users doing the same task in a gamified and a non-gamified manner.

The results shown in Fig. 8 show the same trend. If we focus on evaluation questions EQ-2 (integration), EQ-3 (evidence on motivation), and EQ-4 (performance), the result is that most papers either develop these aspects of gamification up to a good level, or they do not even consider them. Many primary studies do not provide any evidence at all on the effect of gamification on players' motivation and performance, since the goal of these primary studies is to present a proposal for gamification, or how it has been incorporated into a CASE tool, but without carrying out an evaluation of the results in a real setting. EQ-1 is the evaluation question that shows the most uniform distribution of scores. This reflects the variability we have found in the methodology followed by each primary study. It is important to note that we did not only evaluate the fact that the primary study followed a methodology or how complete that methodology is, but also to what extent that methodology could be applied in a different organization.

5. Discussion

In this section we provide a discussion of the results obtained from the classification and analysis of the studies, along with an identification of gaps and opportunities for future research.

As a result of this analysis, the first point to highlight as a result of this study is that the application of gamification in Software Engineering is still in a very initial stage. As can be observed in the results shown in the previous section, most of the studies selected have been published in workshops or conferences (only 7% of the studies were published as journal articles), which denotes that the status of the research is still preliminary. In addition, the number of papers providing sound evidence of the impact of gamification in SE is small; the empirical evidence about the potential usefulness of gamification in SE is therefore scarce and there is vast empirical work to do to make this body of knowledge more mature. In this sense it is important to recall the "lemmingineering" term coined by Davis [28]. As Gamification is indeed a current trend in which a lot of effort has been invested; it is being successfully applied in a lot of domains, mainly to foster customer loyalty

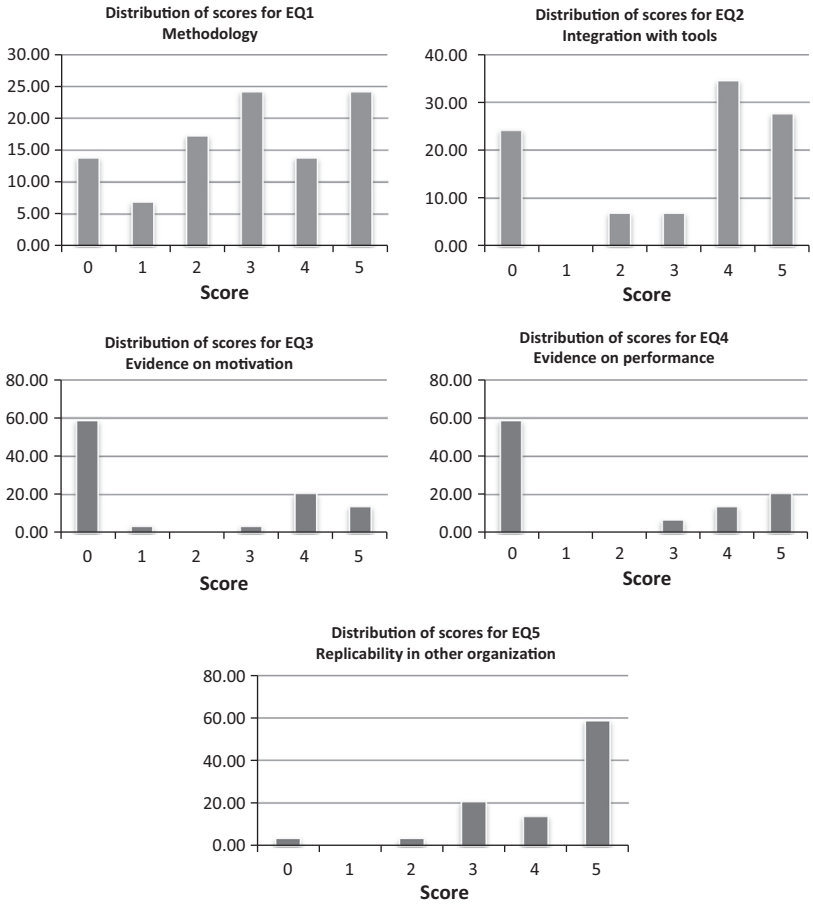

Fig. 8. Distribution of scores.

Table 10
Results of the subjective evaluation of the primary studies.

Evaluation question	Average	Standard deviation
EQ1	2.90	1.70
EQ2	3.10	1.95
EQ3	1.66	2.13
EQ4	1.79	2.23
EQ5	4.17	1.23

and improve employee engagement. But will it be equally successful in the Software Engineering field? If we analyze the nature of software, with features making its development human-intensive, the potential of gamification is even higher. Many software engineering tasks, such as testing and maintenance, are considered somewhat "destructive" and not very appealing; i.e., this type of work is not intrinsically motivating, so specific mechanisms to foster motivation are needed. In this scenario, gamification can be a very encouraging area to incorporate. But that does not mean we should fall into "lemminginering gamification", i.e., "do not follow a path just because everybody's doing it" [28]. Gamification is a very important path that cannot be ignored, but we must be cautious about the way in which gamification can be effectively applied in the SE field (see Fig. 9).

Another important aspect we identified during the analysis is the type of game designs proposed in the primary studies. The studies chosen based gamification on the application of the most traditional game mechanics, such as points, levels, and badges. Actually, from the data provided in Fig. 8 we can observe that in more than half the studies, the only game mechanics applied were points and badges. It has still not been demonstrated which of the mechanisms are most suitable; some studies, for instance, report that leaderboards are the most important mechanics, while others underline the importance of badges. Regarding the issue of game design and which game mechanics to apply, we should not forget the prediction by Gartner [6] that by the present year, "80% of the gamified applications will fail to meet their business goals due to a poor design". We observe from the studies selected that application of gamification in SE has emphasized what we could term "pointification", since the main mechanics applied rely on the assignation of points to tasks, badge collection and the creation of rankings. Gamification is a wider area in which a lot of mechanics exist [2,3,7], but most importantly it is an area in which there are suitable dynamics for taking advantage of those mechanics to engage and motivate players in the best way [2,3,7]. This is the most important challenge as we seek to turn gamification into a key asset in the SE field.

Interesting conclusions can also be extracted regarding the process areas that have been the object of gamification. Software implementation is the area that attracted most interest in the primary studies we analyzed. Software requirements management has also been an object of study, but only in the activities of requirements elicitation and analysis with the customer. Despite how interesting these activities are, others have not been considered, such as change management, for example. Other process areas have attracted less attention. In the case of project management and control, the only study we found looks at task estimation and monitoring. Other areas such as software testing and configuration management are considered in some studies, but they are not dealt with fully. The lack of papers studying gamification in other process areas highlights another important opportunity for

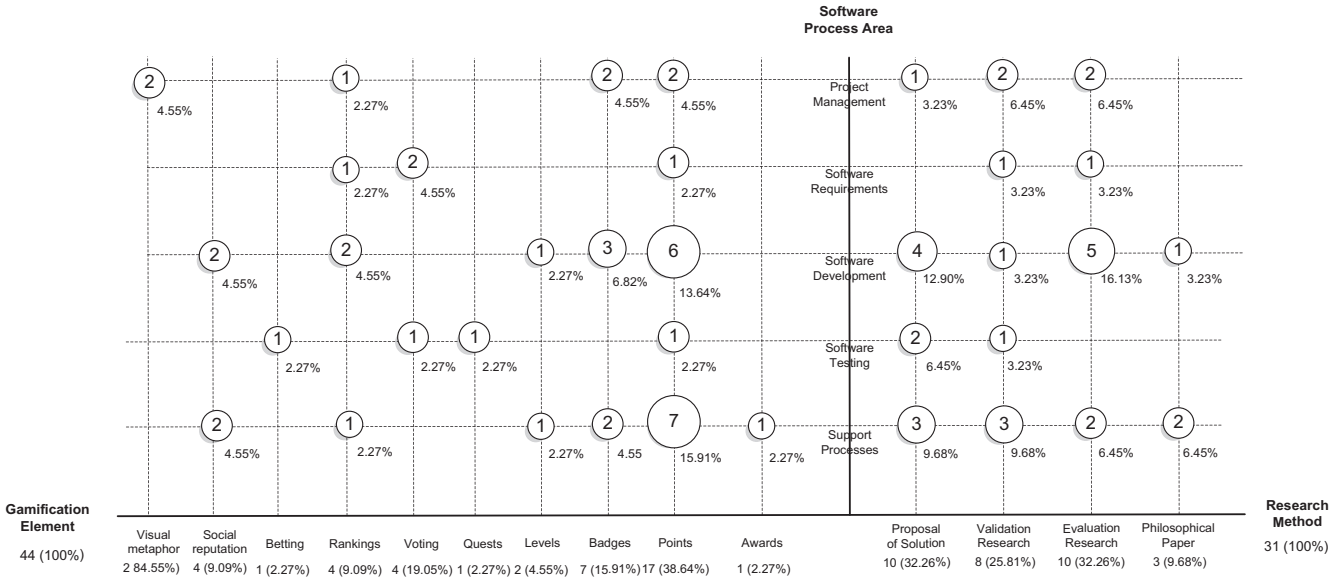

Fig. 9. Summary of classification.

research. Areas such as software project management, testing, or maintenance are also attractive targets for research on gamification applied to SE.

In addition, we have detected a lack of methodological support. Proposals focus on the traditional game mechanisms which can be applied, but no systematic way to apply them is proposed. Even more importantly, we miss support for the initial stages of application of gamification, in which goals must be formalized, players must be characterized and then on that basis the mechanics and dynamics have to be chosen. There are many aspects to consider and support in the gamification of a software application or a workplace environment, one of them being to get a deep knowledge of the player profiles and their characteristics, going on to design an environment that appropriately matches those player profiles. The same game will not produce the same effect on different players, so tailoring the game to fulfill different types of player satisfaction is a crucial aspect to bear in mind.

Finally, the way gamification is incorporated into the SE workplace is other aspect deserving further research effort. In many cases, gamification is incorporated as a new tool that is developed ad-hoc for this purpose. We believe that gamification should be smoothly integrated into an organization's infrastructure and the tools composing it in order for it to be successful. Defining the procedures and tools of a complex organization is no easy task, usually requiring great effort and investment. In addition, the tools used by the different participants are part of the organization's culture. This means that a proposal for gamification that does not appropriately integrate with existing procedures and tools will have few chances of being successful in a sustainable way. Again, integration should be considered as an important aspect of a successful gamification design [29].

6. Conclusions and future work

In this paper a mapping study has been conducted to characterize the state of art as regards the application of gamification in SE. The focus of this systematic mapping was gamification applied to SE, thus leaving serious games out of the scope of the study. After carrying out the search for primary studies, we classified them according to four facets, namely the process area(s) they considered, the type of gamification elements and mechanics they used in their proposals, the kind of research, and the sort of forum in which the primary study was published. We also carried out a subjective evaluation of the primary studies, seeking to analyze how they considered aspects such as supporting methodology, experimental evidence about impact on user engagement and performance, integration with the organization's tools, as well as the degree to which the proposals of each primary study can be replicated in other organizations/settings.

The results we obtained during the analysis of the primary studies show that the existing research on gamification applied to SE is very preliminary or even immature, since most studies have been published in workshops or conferences, and few of them offer sound empirical evidence of the impact of their proposals on user engagement and performance. Further research providing empirical results about the effect of gamification would give us interesting knowledge.

Most of the studies we have analyzed focus on software development processes, followed by some of the activities of software requirements, project management and configuration management. We consider that this shows up an important gap in the field, since many important software process areas have not been studied to their full extent; these areas include software project management, requirements, or maintenance.

Another aspect that deserves further research effort is the type of game design and game elements used in the proposals found in the primary studies. According to the results of our classification, more than 38% of the studies consider only the simplest gamification element, namely rewarding user's behaviors with points, which could be called "*pointification*", instead of gamification. In our opinion, this can be a dangerous trend. The lack of user profile analysis, appropriate design methods, and gamification schemas which are too simple, can lead to applications achieving results below their expectations, risking the fulfillment of the Gartner prediction [28].

Another related research gap which we found during the study is the lack of a systematic methodology to incorporate gamification in SE and thus improve user engagement and performance. In our opinion, and according to existing literature on gamification, the process of gamifying a work environment should follow a series of steps directed at obtaining better results and performance, as well as on improving clearly-identified business goals. This lack of methodology makes most proposals immature and difficult to replicate successfully in other domains.

In addition, in the proposals providing a gamified tool, it is our conviction that the incorporation of gamification has not been

correctly integrated with the tool ecosystem of the organization. Again, this makes most case studies difficult to evaluate and to replicate in other domains. For example, gamification should be integrated into the existing tools of the company, instead of new ones being provided.

In those primary studies presenting a real implementation of their proposal, gamification is often incorporated into an independent tool, usually developed ad-hoc for this purpose. In our opinion, the lack of guidelines and solutions for integrating gamification with the organization's tool ecosystem is a weakness of the existing research in the field. Most companies devote significant effort and investment to building their work methodology and supporting tools. In our opinion, a gamification solution that does not integrate appropriately with the organization's tools faces an important challenge to provide improvement results sustainably.

From the results of the systematic mapping, we observe that the adoption or gamification in SE is going more slowly than in other domains such as marketing, education, or mobile applications. This trend is in some way similar to that of the adoption of automation in SE by means of CASE tools. Although the number of proposals of gamification in software engineering is still small, its evolution allows us to believe that this field will experience significant growth in the next few years. It is also our view that few of the existing proposals address the problem in a systematic way that can be replicated in other software process areas or contexts; only certain process areas have been explored up to now. There is, moreover, significant variety in the type of research methods that have been applied, as well as variance in the conclusions they obtain.

This systematic mapping was carried out as part of a wider project (*GOAL – Gamification on Application* Lifecycle) devoted to the application of gamification in SE engineering; in this project new tools and proposals are being developed from the results obtained and conclusions are being reached from this study. The results of this systematic mapping have served as the basis for further developments in the scope of this project, more particularly regarding a methodology supporting the application of gamification in SE. These developments also include a general framework to accommodate gamification solutions and their integration with the existing assets of the organization.

Acknowledgements

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Appendix A. Complete list of all primary studies included in the study

[A1] D. Ašeriškis and R. Damaševičius, "Gamification of a Project Management System," presented at the Proceedings of the 7th International Conference on Advances in Computer-Human Interactions (ACHI'2014), 2014.

[A2] D. F. Bacon, D. C. Parkes, Y. Chen, M. Rao, I. Kash, and M. Sridharan, "Predicting your own effort," in *Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems (AAMAS'12)*, 2012, pp. 695–702.

[A3] J. Bell, S. Sheth, and G. Kaiser, "Secret ninja testing with HALO software engineering," in *Proceedings of the 4th international workshop on Social software engineering (SSE'11)*, 2011, pp. 43–47.

[A4] A. A. de Melo, M. Hinz, G. Scheibel, C. D. M. Berkenbrock, I. Gasparini, and F. Baldo, "Version Control System Gamification: A Proposal to Encourage the Engagement of Developers to Collaborate in Software Projects," presented at the Proceedings of the 6th Int. Conf. on Social Computing and Social Media (SCSM'2014).

[A5] S. Dencheva, C. R. Prause, and W. Prinz, "Dynamic Self-moderation in a Corporate Wiki to Improve Participation and Contribution Quality," presented at the Proceedings of the 12th European Conference on Computer Supported Cooperative Work (ECSCW'11), 2013.

[A6] A. Dorling, McCaffery, F., "The gamification of SPICE," *Communications in Computer and Information Science*, vol. 290, pp. 295–301, 2012.

[A7] D. Duarte, C. Farinha, M. M. da Silva, and A. R. da Silva, "Collaborative Requirements Elicitation with Visualization Techniques," presented at the Proceedings of the IEEE 21st International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE'12), 2012.

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[A13] S. Nikkila, D. Byrne, H. Sundaram, A. Kelliher, and S. Linn, "Taskville: visualizing tasks and raising awareness in the workplace," presented at the Proceedings of Conference on Human Factors in Computing Systems (CHI'2013), 2013.

[A14] S. Nikkila, S. Linn, H. Sundaram, and A. Kelliher, "Playing in Taskville: Designing a Social Game for the Workplace," presented at the Proceedings of Int. Conf. on Computer Human Interaction (CHI'2011) – Workshop on Gamification: Using Game Design Elements in Non-Game Contexts, 2011.

[A15] E. B. Passos, D. B. Medeiros, P. A. S. Neto, and E. W. G. Clua, "Turning Real-World Software Development into a Game," in *Proceedings of the Brazilian Symposium on Games and Digital Entertainment (SBGAMES'11)*, 2011, pp. 260–269.

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[A19] S. K. Sheth, J. S. Bell, and G. E. Kaiser, "Increasing Student Engagement in Software Engineering with Gamification," CUCS-018-12, Technical Report, Columbia University, Department of Computer Science, 2012.
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[A21] L. Singer and K. Schneider, "Influencing the adoption of software engineering methods using social software," presented at the Proceedings of the International Conference on Software Engineering (ICSE'12), 2012.
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[A25] R. Sukale and M. S. Pfaff, "QuoDocs: improving developer engagement in software documentation through gamification," presented at the Proceedings of the 32nd ACM Conference on Human Factors in Computing Systems (ACHI'2014), 2014.
[A26] J. Thom, D. Millen, and J. DiMicco, "Removing gamification from an enterprise SNS," in *Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW'12)*, 2012, pp. 1067–1070.
[A27] R. Troughton, "Gamification in Software Development and Agile," *Software Developer's Journal*, 2012.
[A28] B. Vasilescu, "Human aspects, gamification, and social media in collaborative software engineering," presented at the Proceedings of the 36th International Conference on Software Engineering (ICSE'2014).
[A29] B. Vasilescu, A. Serebrenik, P. Devanbu, and V. Filkov, "How social Q&A sites are changing knowledge sharing in open source software communities," presented at the Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing (CSCW'2014), 2014.

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