Adaptive Gamification in Collaborative systems, a Systematic Mapping Study

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Abstract

Mass collaboration mediated by technology is now commonplace (Wikipedia, Quora, TripAdvisor). Online, mass collaboration is also present in science in the form of Citizen Science. These collaboration models, which have a large community of contributors coordinated to pursue a common goal, are known as Collaborative systems. This article introduces a study of the published research on the application of adaptive gamification to collaborative systems. The study focuses on works that explicitly discuss an approach of personalization or adaptation of the gamification elements in this type of system. It employs a systematic mapping design in which a categorical structure for classifying the research results is proposed based on the topics that emerged from the papers review. The main contributions of this paper are a formalization of the adaptation strategies and the proposal of a new taxonomy for gamification elements adaptation. The results evidence the lack of research literature in the study of adapting gamification in the field of collaborative systems. Considering the underlying cultural diversity in those projects, the adaptability of gamification design and strategies is a promissory research field.

Keywords: Adaptive gamification, Collaborative systems, Systematic mapping

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1. Introduction

Mass collaboration mediated by technology is now commonplace. In *TripAdvisor.com*, millions of users consult, create, comment, and vote travel-related reviews, transforming this website in one of the most up-to-date sources of information for travelers [1]. Similarly, large numbers of participants are required for the continuous success of Q&A sites. Examples of these are *Quora* or *StackExchange*, and of course, Wikipedia. On-line, mass collaboration is also present in science in the form of Citizen Science. Zooniverse, one of the largest communities of citizen scientists, reported in 2016, 1.6 million volunteers contributing to over 100 projects [2].

The examples mentioned above have common features such as having a desirably large and dynamically formed community of contributors spread across the world, carrying out concerted efforts on behalf of a common objective. Furthermore, they have specific coordination mechanisms to share and consolidate their knowledge and have a particular type of retribution for the contributors' performed tasks [3]. Wikis, social art, gamification, crowdsourcing are social technologies [4] that could be analyzed in the same layer of understanding. In this article, the mentioned collaboration models are called **collaborative systems**.

Collaborative systems must consider strategies and mechanisms to convene participants, keep them active and committed with the specific project's task, keep them engaged with the project, and make them feel part of it. It is also necessary and important that the collaborative projects' participants vary in terms of profiles and cultural characteristics.

In many cases, participation in collaborative systems is voluntary. Therefore, planning the objectives of the project or ensuring the sustainability of the tasks is not possible. For example, Wikipedia suffers from having articles that, when not updated, begin an aging stage and lose validity. On the other hand, in crowdsourcing projects, if a task is planned for a certain minimum number of participants, and that number is not reached, it cannot be carried out.

In the last years, the use of games has been adopted as a strategy to engage volunteers' participation in collaborative systems. Two main related approaches are exploited in this sense: serious games and gamification. *Serious games* describe the design of full-fledged games for non-entertainment purposes[5]. A well-known application of serious games in science is the Foldit project, in which players interactively solve a puzzle to manipulate protein structures[6]. *Gamified applications* incorporate elements of games into a software application [7]. The main difference with serious games is that in gamification, the player is conscious of doing a specific task that is not a game. An appropriate example of the use of gamification in citizen science is "I want to be a Captain!" project [8] in Zooniverse[1]. In this case, volunteers transcribe handwritten pages of 19th-century ship logs. According to the amount and quality of the transcriptions, volunteers progress in a sailor rank from Cadet to Captain.

Despite the rapid growth of the gameful design research area, and the actual level of success in the user's engagement that it reveals, these findings are not general in terms of domain, and they cannot be generalized to all users. The *one-size-fits-all* approach presents several limitations because of the different motivations, personalities, needs, or values of the users [9, 10]. Currently, the research stream on adaptive gamification is taking care of the gamification that each particular user needs in a particular moment, tailoring the gamification to the users and contexts[11, 12]. For example, adaptation can be made on many aspects: the game storytelling, the game difficulty, the content generation, the guidance or hinting on the goals, the presentation, the curriculum sequencing, among others [13]. Nevertheless, the existing adaptive gamification approaches are not directly applicable to collaborative systems, given that they do not necessarily focus on the community aspect.

This work surveys existing approaches to adaptive gamification in the context of collaborative systems projects through systematic mapping studies and

[1]https://www.zooniverse.org/get-involved/education accessed on 29th March 2020

literature reviews, and systematically [14] codifies the articles collected from Scopus, the ACM Digital Library, the IEEEXplore collection, and Springer. The research question of this paper is: *Which approaches were designed and applied to customize or adapt the gaming experience to different users in the context of collaborative systems?*.

This paper is structured as follows: in Section 2 the related work is described, Section 3 describes the planning of the systematic mapping. Then, in Section 4 the results of the application of the classification scheme are explained, and finally the conclusions are discussed in Section 6.

2. Related Work

At the time of starting this research, no related works (systematic mappings, literature reviews) were found discussing the adaptation of game elements and game mechanics in collaborative systems. Nevertheless, an overview of existing secondary studies can be done.

Some specific revisions have been conducted on gamification applied to learning contexts, such as in De Souza Borges et al. [15] and Majuri et al. [16]. Particularly, the latter work analyzed several of the reviewed papers from the lens of behavioral and psychological outcomes.

Other works focus on gamification applied in domains such as software engineering, like in Pedreira et al. [17], information systems like in Schlagenhaufer et al. [18], or gamification design frameworks (Azouz et al. [19]). None of these tackle the dimension of collaborative software projects.

The work in Morschheuser et al. [20] cares about crowdsourcing participants' motivation and their relationship with gamification strategies. However, the authors concluded that too little research had been conducted to draw definite conclusions on which specific implementations would work better or worse in certain situations, and it does not address adaptation or personalization of gamification elements.

Finally, two reviews on the adaptation of gamification have been found, but none of them focusing on collaborative software systems. The work in Stuart et al. [21] analyzes the approaches of adaptive gamification in learning domain, comparing the presented strategies to relate the input of adaptation (user profile or activity) with the effects of adaptation in terms of game elements' change, and in terms of the impact on learners. Although the work in Tomé Klock et al. [22] identifies which adaptation and personalization techniques (in terms of user model) have been used in gamification, it lacks precision about the computational paradigms that have been applied in the primary works. Similarly, Böckle et al. in [9] surveyed the effectivity of gamification approaches and mapped the relationship between gamification elements and user profiles. Additionally, they identified different degrees of adaptivity among the identified gamification literature.

Despite the advancement contributed by all these research groups, we find the field of adaptive gamification on collaborative software systems to be incipient, and so a review study is still unavailable.

3. Research method

This article follows the systematic mapping guidelines defined by Petersen et al. in [14] to map the scientific work in a given research area to identify the state-of-the-art. The proposed methodology requires the definition of research questions, searching for relevant papers, screening papers, keywording of abstracts and data extraction, and mapping into categories. This section details the data sources and how the search strategies, classification, and evaluation criteria were planned with such an objective.

3.1. Research Questions

The definitions of personalization and adaptation are discussed topics around the static versus dynamic aspect. Static in terms of user's preferences at the beginning of the game is usually done explicitly. On the other hand, the dynamic approach refers to a user experience that gets modified through time without explicit user intervention.

Table 1: Research Questions

Nr.	Research question
RQ1	What are the approaches of **personalization** in gamified collaborative systems?
RQ2	What are the approaches of **adaptation** in gamified collaborative systems?
RQ3	What **gamification elements** have been used in the adaptation in gamified collaborative systems?
RQ4	Which **research methods** have been used in the evaluation of adaptation in gamified collaborative systems?
RQ5	Which **user models** have been used in adaptation of gamified collaborative systems?

This article follows the definition of Göbel et al. [13]: "The personalization is considered as the static one-time adaptation of a gaming aspect to the needs or preferences of a user, whereas adaptation refers to the continuous adjustment of the game based on the actions and performance of a user and the current state of the game towards a desired state."

The research questions attempt to provide deepen the relevant aspects of the current work in adaptation and personalization in gamified collaborative systems. These questions, summarized in Table 1, conduct the description of the surveyed approaches in terms of personalization: Has the user a way of changing some game setting?; adaptation: What aspects of the game are adapted?; gameful design: Which game elements or mechanics are used?; research methods: How are the approaches evaluated?; user model: A profiling of the user (as a player or learner) is done?

3.2. Data sources and search strategy

The scope of the search included the articles published in academic forums and publications (including journal and conference or workshop papers) bounded to the years 2009 to 2019. The main terms of this search were 'adap-

Table 2: Search terms

Major terms	Alternative or synonyms terms
Adaptation	adaptation, adaptive, adaptability, adaptivity, customization, customizing, personalization, personalize, evolutionary
Gamification	gamifying, gamify, gameful design, gamefulness, funware, serious games
Collaborative	Crowdsourcing, Collaborative software, Citizen Science, People power, Community Science

tation,' 'gamification,' and 'collaborative.' Alternative spellings, synonyms, or related terms were incorporated, to avoid narrowing the search. See the details in Table 2. The chosen data-sources were Scopus, the ACM Digital Library, the IEEEXplore collection, and Springer.

This study excluded those papers that developed gamification in other domains rather than collaborative software systems, or those that applied game theory to resolve computation problems. Proceedings, book chapters, duplicated papers of the same research in different databases, and papers available only in abstracts or presentations were also excluded. Inclusion and exclusion criteria are summarized in Table 3.

The selection strategy is summarized in Table 4 and follows the steps described below:

1. Apply a query string to each data source search engine; the details of the query string can be found in Appendix A.
2. Export from the query results, the title, abstract, and authors of each paper to a CSV file.
3. Filtering duplicated entries.
4. Applying the inclusion/exclusion criteria over abstracts and keywords
5. Reading of full text to review and classify primary articles.

The filter of duplicated entries and the review and analysis of the primary

Table 3: Inclusion/exclusion criteria

Inclusion	• Papers that fulfill the search string • Academic journal, conference, and workshop papers. • Discipline: Computer Science • Abstract and keywords are available • Publicated between 2009 and 2019.
Exclusion criteria for titles and abstract	• Proceedings • Papers written in other language different than English. • Papers out of scope (not collaborative projects)
Exclusion criteria for full text	• Publications without abstract • Papers without adaptation strategy

Table 4: Summary of selection strategy

	Selection strategy
Datasources	Scopus, ACM Digital Library, IEEEXplore and Springer
Target items	Journal paper, Conference papers, Workshop papers
Language	Papers written in English
Data fields	Title, Abstract, Keywords
Publication Period	since 2009 to 2019

Table 5: Adaptation in Serious Games by Kickmeier-Rust[23]

Criteria
Procedural and adaptive level and content generation
Adaptive behavior of agents
Adaptive and interactive storytelling
Guidance, hinting
Motivational interventions
Adaptive presentation
Adaptive curriculum sequencing
Navigation support
Intelligent solution analysis

works was done using the Scolr[2] systematic review tool. Scolr offers collaboration support to create open literature reviews.

3.3. Data extraction

To map the primary articles, this study proposes a preliminary data form with a list of fields related to the research questions. Nevertheless, through the classification stage, this scheme has evolved to give place at new dimensions or

[2] `http://scolr.cientopolis.org/` accessed on 12th May 2020

Table 6: Game mechanics and gamification design principles

Game mechanics	points, badges, levels, progress bars, leaderboards, virtual goods and avatars
Gamification design principles	Goals/challenges, Personalization, Rapid feedback, Visible status, Unlocking content, Freedom of choice, Freedom to fail, Storyline/new identities, Onboarding, Time restriction, Social engagement

Table 7: Reseach methods by Wieringa et al.

Category	**Description**
Validation Research	Techniques investigated are novel and have not yet been implemented in practice. Techniques used are, for example, experiments, i.e., work is done in the lab.
Evaluation Research	Techniques are implemented in practice, and an evaluation of the technique is conducted.
Solution Proposal	A solution for a problem is proposed; the solution can be either novel or a significant extension of an existing technique.
Philosophical papers	These papers sketch a new way of looking at existing things by structuring the field in the form of a taxonomy or conceptual framework.
Opinion papers	These papers express the personal opinion of somebody whether a specific technique is good or bad or how things should be done. They do not rely on related work and research methodologies.
Experience papers	Experience papers explain what and how something has been done in practice. It has to be the personal experience of the author.

merge, and split existing categories.

The first research question deals with the available customization strategy described in the primary works. As most of them did not include evidence of customization information and there is no standard taxonomy, the most relevant information is in terms of a class definition built ad-hoc from primary articles. The taxonomy is divided into the following categories: *none, not specified, avatar, personal description, game environment, role choosing, and team building.*

The second research question concerns approaches of adaptation in gamified collaborative systems (RQ2) and it is analyzed in terms of difficulty adaptation, and the adaptive storytelling, following the proposal of Göbel and Wendel's [13]. Furthermore, Kickmeier-Rust and Albert [23] identified a set of adaptation principles, techniques, and methods relevant to the serious games design perspective. This set is also used in this work as classification criteria and is detailed in Table 5. Nevertheless, after the data extraction and mapping, other criteria for the classification had emerged, which is explained in Section 4.3.

On the other hand, to further recognize game elements in the surveyed publications (RQ3), we identified the use of game mechanics and gamification design principles compiled by Dicheva et al. [24]. These are all detailed in Table 6. Nevertheless, the existing literature-review publications on gamification was surveyed, and although no standard classification of game elements was found, it must be mentioned that there are different approaches to describe them. At framework levels like the MDA [3] Framework proposed by Hunicke et al. [25], more fine-grained proposals like the game mechanics of Zichermann et al. [26] or the taxonomy of common gamification elements concerning an anticipated user commitment presented by Robinson and Belloti in [27].

Regarding the research question about the method used in the development and evaluation of the proposed approaches (RQ4), we applied the classification criteria proposed by Wieringa et al. in [28] that is detailed in Table 7.

[3] Mechanics, Dynamics, and Aesthetics

Table 8: Number of results by datasource

Datasource	**Search results**
ACM	101 items
Scopus	334 items
IEEExplore	118 items
Springer	197 items
Total	750 items

Finally, RQ5 focuses on player modeling. Player types or models are archetypal reasons or motivations that explain why players play games [21, 13]. Smith et al. [29] compile a long list of player models, including the well-known Bartle's model that organizes players in four categories, considering how they interact with the other players and the game world, which are: Achiever, Killer, Socializer, and Explorer [30]; and the evidence-based gamification user type Hexad [31]. In the current study, when the primary works explicitly mention the implemented player model, this is quantified in the corresponding class. However, in other cases, when possible, the player model is described in terms of Bartle's model.

3.4. Search

The details over the search strings are given in Appendix A, and Table 8 is shown the number of search results per database, in total: 750 articles. Then, 58 duplicated articles were filtered automatically by the use of the *Scolr* tool. Hence, the results were reduced to 692 papers.

In the following section, the results are manually reviewed, filtered, and the research questions are answered.

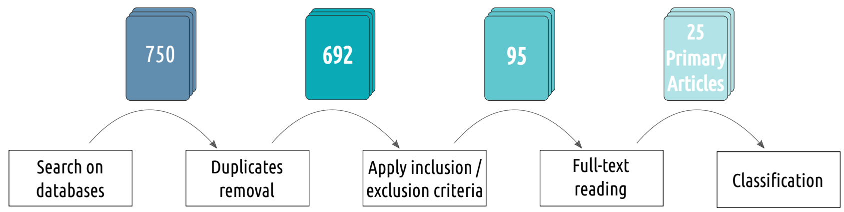

Figure 1: Search and filtering process

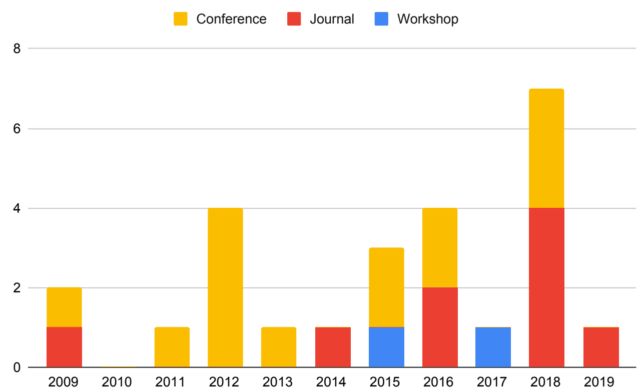

Figure 2: Distribution of primary articles by year and type of forum

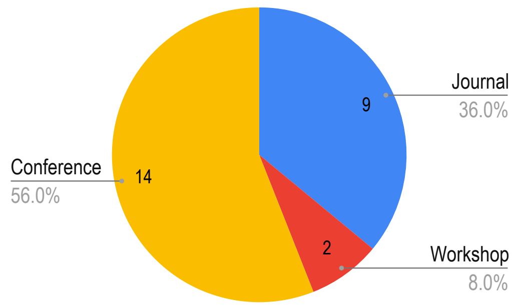

Figure 3: Venue types

Table 9: Primary studies (part 1 of 2)

Title	Authors	Year	Forum	Reference
Automatic content generation in the Galactic Arms Race video game	Hastings et al.	2009	Journal	[PA1]
Non-invasive Assessment and Adaptive Interventions in Learning Games	Kickmeier-Rust et al.	2009	Conference	[PA2]
Wemakewords - An adaptive and collaborative serious game for literacy acquisition	Ismailovi et al.	2011	Conference	[PA3]
Motivating elderly people to exercise using a social collaborative exergame with adaptive difficulty.	Cantwell et al.	2012	Conference	[PA4]
Training conflict management in a collaborative virtual environment	Emmerich et al.	2012	Conference	[PA5]
Designing collaborative multiplayer serious games for collaborative learning: Escape from Wilson Island - A multiplayer 3D serious game for collaborative learning in teams.	Wendel et al.	2012	Conference	[PA6]
A sequential recommendation approach for interactive personalized story generation	Yu et al.	2012	Conference	[PA7]
Architecture for monitoring learning processes using video games	Padilla-Zea et al	2013	Conference	[PA8]
A multi-agent architecture for collaborative serious game applied to crisis management training: Improving adaptability of non played characters	Oulhaci et al.	2014	Journal	[PA9]
Improving Paid Microtasks through Gamification and Adaptive Furtherance Incentives	Feyisetan et al.	2015	Conference	[PA10]
The Squares: A Multi-touch Adaptive Game for Children Integration	Llanos et al.	2015	Conference	[PA11]
Gamification of Collaborative Learning Scenarios: Structuring Persuasive Strategies Using Game Elements and Ontologies	Challco	2015	Workshop	[PA12]
Lu-Lu: A framework for collaborative decision making games	Daylamani-Zad et al.	2016	Journal	[PA13]
Gamification of cognitive training: A crowdsourcing-inspired approach for older adults.	Mora et al.	2016	Conference	[PA14]
Agent Supported Serious Game Environment	Terzidou et al.	2016	Journal	[PA15]
Generating Multiplayer Games for Interaction Learning using Game Design Patterns	Tregel et al.	2016	Conference	[PA16]
Profile-based algorithm for personalized gamification in computer-supported collaborative learning environments	Knutas et al.	2017	Workshop	[PA17]
Reflective Agents for personalization in collaborative games	Daylamani-Zad et al.	2018	Journal	[PA18]

Table 10: Primary studies (part 2 of 2)

Title	Authors	Year	Forum	Reference
Examining competitive, collaborative and adaptive gamification in young learners' math learning	Jagušt et al.	2018	Journal	[PA19]
Plunder Planet: An Adaptive Single- and Multiplayer Fitness Game Environment for Children and Young Adolescent	Martin-Niedecken	2018	Conference	[PA20]
Game-based crowdsourcing to support collaborative customization of the definition of sustainability	Nik Bakht	2018	Journal	[PA21]
Role-based Multiplayer Content Online Adaptation in Large-scale Scenarios	Tregel et al.	2018	Conference	[PA22]
A Semantic Graph-Based Japanese Vocabulary Learning Game	Wita et al.	2018	Conference	[PA23]
An Adaptive Feedback System to Improve Student Performance Based on Collaborative Behavior	Awais et al.	2019	Journal	[PA24]
A process for designing algorithm-based personalized gamification	Knutas et al.	2019	Journal	[PA25]

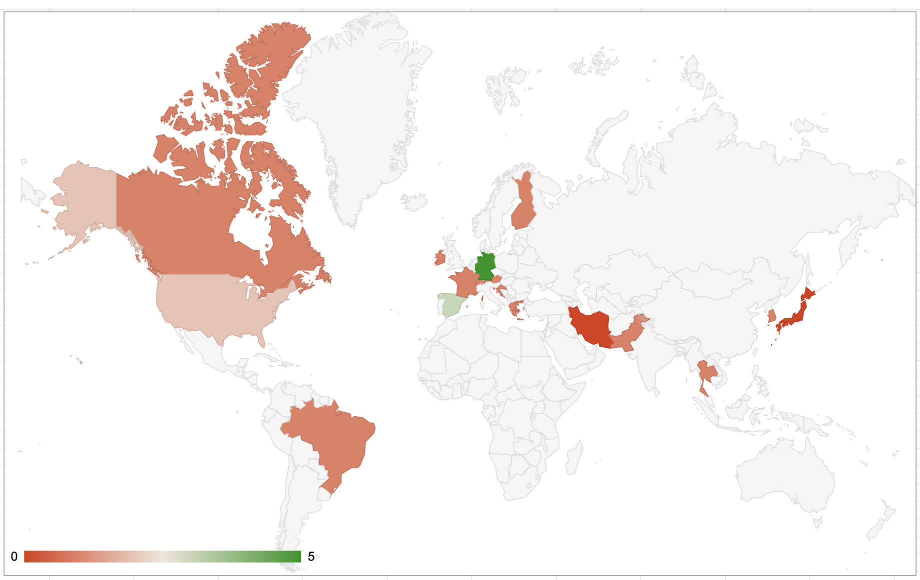

Figure 4: Countries of the authors' affiliations

4. Results of systematic mapping

4.1. Search results

As was described in the previous section, the search process had four main steps. The first one is the application of the search in databases, the second one is the removal of duplicated papers, the third one is the application of inclusion and exclusion criteria, and finally, the full text reading to determine the set of primary articles. See Figure 1 for details.

During the third step, the search results related to adaptation in other domains rather than collaborative systems were discarded by reading each one's title, keywords, and abstract. Also, those wrongly included due to a different use of any of the terms were discarded, which led to a set of 95 papers. The full-text reading of the articles determined a set of 25 primary studies (see Tables 9 and 10). The works that applied the game theory or presented full-fledged games or serious games with no application on a collaborative system were discarded.

The articles' exclusion rate through the filtering steps of this mapping is similar to those in related works [14] [18]. The complete list of primary studies is detailed in 6.

Figure 2 shows the distribution of the primary studies between the years 2009 and 2019, distinguishing among conferences, journal and workshop papers. While Figure 3 provides an overview of the distribution of the mapped articles among these venues, and it can be seen that the number of conference papers is higher (56%) than the number of journal papers(36%), and finally, the workshop articles (8%).

In terms of the authors affiliation countries, Germany was the most frequent, as shown in Figure 4. The international collaborations were seen among Brazil and Japan [PA12], Croatia and South Korea[PA19], and Finland, Belgium and Italy[PA25].

The selected primary studies must be analyzed from the different perspectives of the research questions, aiming at answering them with the extracted data. In the following subsections, a detailed analysis of each question is given.

Table 11: Personalization approaches by primary study

Paper	None	Not specified	Avatar	Self defining	Game	Team building	Role choosing
[PA1]					•		
[PA2]		•					
[PA3]			•				
[PA4]			•				
[PA5]	•						
[PA6]					•		
[PA7]	•						
[PA8]						•	
[PA9]							•
[PA10]	•						
[PA11]	•						
[PA12]	•						
[PA13]	•						
[PA14]			•				
[PA15]			•				
[PA16]	•						
[PA17]				•			
[PA18]	•						
[PA19]	•						
[PA20]		•					
[PA21]	•						
[PA22]		•					
[PA23]	•						
[PA24]	•						
[PA25]				•			

References. Self defining: Self-defining user type questionnaire; Game: Game Environment

4.2. RQ1: What are the approaches of personalization in gamified collaborative systems?

The first aspect that was analyzed is the personalization ability of the primary studies' approaches. Even though they might not have a dynamic or computed adaptation, personalization allows setting a difference among users and, therefore, a different gaming experience.

As shown in Table 11, most of the primary studies did not consider a personalization strategy; this is: there is no mechanism for the user to customize the game setup or preferences. In 3 articles, this personalization possibility is not specified. In the others 10 articles, the following personalization strategies have been identified: the selection of the background music [PA1]played during the game, choosing the game environment camera [PA6], customizing different characteristics of its avatars [PA3][PA4][PA14][PA15], describing the user type [PA25][PA17][PA9] either by selecting a role or filling a survey, or building a team [PA8].

By last, it is important to notice that it was not found a dependency between personalization capacity and adaptivity in the reviewed articles. For example, the personalized element was not considered within the adaptation approach.

4.3. RQ2: What are the approaches to adaptation in gamified collaborative systems?

As outlined in Section 3.3, the adaptation aspects have been considered with different criteria, regarding the difficulty adaptation, the storytelling adaptation, and the well-known taxonomy proposed by Kickmeier-Rust and Albert [23] listed in Table 5. The data extraction of primary articles concerning these criteria is summarized in Table 12.

4.3.1. Difficulty adaptation

Collaborative systems must care about mitigating the participants' desertion related to the fear of being wrong. For example, the Zooniverse citizen science project encourages participants not to worry if they make a mistake, because

Table 12: RQ2: Adaptation approaches

Paper	**Difficulty**	**Storytelling**	**Kickmeier-Rust & Albert**								
			PCG	**CCL**	**AGT**	**STR**	**GDN**	**MTV**	**PST**	**NAV**	**ISA**
[PA1]	∅		•		•	•			•		
[PA2]	∅				•		•	•			
[PA3]	•		•	•			•				
[PA4]	•		•		•		•				
[PA5]					•	•					
[PA6]					•		•				
[PA7]		•				•					
[PA8]	•				•		•				
[PA9]		•		•	•	•	•			•	
[PA10]			•					•			
[PA11]	•		•								
[PA12]	∅	∅	•	•				•			
[PA13]			•		•			•			
[PA14]	•		•								
[PA15]					•		•	•			
[PA16]			•								
[PA17]	•			•							
[PA18]			•		•			•			
[PA19]	•		•					•			
[PA20]	•		•								
[PA21]	•		•								
[PA22]			•								
[PA23]	•		•	•							
[PA24]			•	•				•	•		
[PA25]			•					•			

References: •: an adaptation approach is explicitly described; ∅: The adaptation approach was not specified

Kickmeier-Rust & Albert PCG: Procedural and adaptive level and content generation, CCL: Adaptive curriculum sequencing, AGT: Adaptive behavior of agents, STR:Adaptive and interactive storytelling, GDN: Guidance, hinting, MTV: Motivational interventions, PST: Adaptive presentation, NAV: Navigation support, ISA: Intelligent solution analysis the system is designed to correct them with the redundancy achieved by the community. Moreover, collaborative systems projects can have different types of tasks or goals, having different complexity, and thus it is an essential issue for these projects to be able to detect those participants that can face more difficult tasks (game goals) and adapt gaming difficulty.

In this review, different difficulty adaptation strategies have been found. In the first place, a stage sequencing can be given where each stage places a task or a set of tasks that requires developing particular skills in previous stages, assessed by the performance in terms of failure or success of a particular player. Examples of this are were found in [PA3][PA4][PA20][PA14][PA23]. An attractive common trait of all previous works is the dominance of adaptation's input as the frequency of failure and success events, ignoring the player's profile (like the age or gender).

Secondly, the global behavior of the group of players was detected as a difficulty adaptation strategy. For example, in the proposed game by Llanos et al. in [PA11] the score and difficulty of the next round of each player are calculated in terms of the player's past performance, and the interchange conditions (collaboration with other players) is also related to difficulty. Similarly, the proposal of Laguöt et al. in [PA19] adapts difficulty by enlarging or reducing the available time for the problem to be solved, this way keeping the students at the edge of their limits. Also, the difficulty adaptation of a game is related to the progression in time of collaborative construction: the earning of points is more difficult as the game is played. In the article [PA21] of Nik et al., players could earn points by classifying tweets under the right class, but as more opinions are gathered (that is, more playing time), the possibility of earning points becomes more complex (the difficulty increases).

From the perspective of monitored systems, the difficulty adaptation can be a recommendation for teachers or tutors. For instance, the work of Padilla-Zea et al. in [PA8] uses agents to collect information about player's performance to purpose difficulty level modification if the player or the group is unable to overcome a challenge in the stated time.

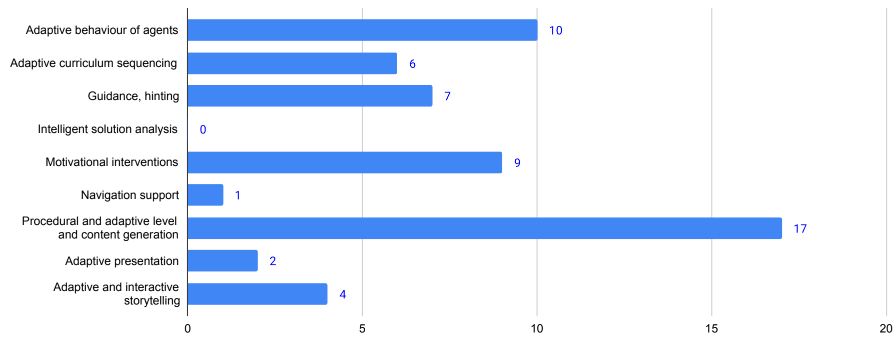

Figure 5: Kickmeier-Rust & Albert adaptation dimension.

Finally, the proposal of Knutas et al. in [PA17] can potentially have a difficulty adaptation if the ruleset is built by properly following the Design Heuristics for Gamification [32]. In particular, whether some characteristics of player (or team) performance were taken into account in setting challenging but manageable goals.

4.3.2. Storytelling adaptation

After the analysis of the papers, only two proposals with storytelling adaptation were found. On the one hand, the work in [PA7] personalizes the users' story according to their storytelling preferences, applying collaborative filtering. They also apply the recommendation system to a history of plot preferences and not to an isolated point in time.

On the other hand, [PA9] proposes an action modeling that characterizes what a player can do during a crisis management situation, using preconditions and effects. The effects can make a change by aborting a goal or validating others.

4.3.3. Kickmeier-Rust & Albert adaptation dimension

Figure 5 shows the comparison of adaptation principles, techniques, and methods in Kickmeier-Rust & Albert taxonomy for the primary studies (see

Table 12 for details). Most of them (eighteen out of twenty-six articles) developed some kind of *procedural and adaptive level and content generation*, in most cases pursuing the objective of managing different levels of difficulty through the adaptation of the game element (more details in Section 4.4).

In second place is the use of *adaptive behavior of agents*, mostly with the aim of including non-player characters [PA5, PA6**?** , PA9, PA15], or to gather information about player behavior or playing experience [PA1, PA2, PA4, PA8, PA13, PA18].

In a third place the *motivational interventions* strategy was detected, aiming at giving tailored feedback or motivating certain behaviors like team work ([PA2], [PA10], [PA12], [PA13], [PA15], [PA18], [PA19][PA24], [PA25]).

The rest of the papers are mainly distributed among adaptive curriculum sequencing and guidance and hinting; and in a lower proportion among adaptive and interactive storytelling, adaptive presentation, and navigation support. None of the primary studies had proposed the Intelligent Solution Analysis.

4.3.4. Expanded adaptation dimensions

Section 3.3 presented an initial set of 9 forms/dimensions of adaptation in serious games found in literature (see table 5). Analysis of the articles in this review revealed three additional dimensions of adaptation, that are specific to collaborative systems: community adaptation, team building, and adaptation frameworks. They further discussed below, and listed in Table 13.

Community adaptation

An adaptive game environment has not only a positive impact on the performance of the individual player as it affects the commitment with game challenge/objective but also can be considered useful in collaborative task resolution. Collaborative systems are characterized by collaborative activities, in which the groups get a benefit from the individuals' actions.

In this context, it is useful to think of an adaptation considering how the community participates in the project, and also, the gamification approaches

Table 13: RQ2: New adaptation dimensions

Paper	**Community**	**Team building**	**Frameworks & Tools**
[PA1]	•		
[PA2]			
[PA3]	•		•
[PA4]			
[PA5]	•		•
[PA6]			
[PA7]	•		•
[PA8]	•	•	•
[PA9]		•	•
[PA10]			
[PA11]	•		
[PA12]			•
[PA13]		•	•
[PA14]	•		
[PA15]	•		
[PA16]		•	•
[PA17]	•		•
[PA18]		•	•
[PA19]	•		
[PA20]			
[PA21]	•		
[PA22]		•	
[PA23]			
[PA24]			•
[PA25]			•

can also motivate the individual participants attending the global preferences through which the community manifests.

The data extraction shown in Table 13 presents a subset of eleven studies where an adaptation on community behavior have been found ([PA1], [PA3], [PA5], [PA7], [PA8],[PA11], [PA14], [PA15], [PA17], [PA19], [PA21]). These approaches can also be sub-classified considering the group work, whether the players have to cooperate in the game.

On the one hand, when players do not work cooperatively, the community status or previous preferences nevertheless can be considered to build an adaptation tailored to individual players. For example, in the work of Hasting et al.[PA1], where game content is automatically generated considering previous choices of the community. The work of Yu et al. [PA7] that recommends story plots considering the ratings of similarly profiled players. Finally, in [PA21] of Nik et al., the individual playing experience changes according to the group contributions, given that the criteria for determining a win is a function on the community contribution: the usage level of a suggested tag by other participants was taken as a quality measure. Previous cases can be seen as an adaptation strategy considering the community interaction and behavior.

On the other hand, when the players are aware of group goals or cooperation in the game, different strategies have been found. In the proposal of [PA15], the agents choose an appropriate message to maintain the attention and reinforce the competition based on the virtual environment and student's actions during a session of the game. Similarly, in the *we make words* game [PA3] of Ismailovi et al. the teamwork is crucial to go to the next round because the game requires all teammates to build their words to complete the group goal. The approach presented by Llanos et al. in [PA11] the game goal or challenge of the team is set up considering the team's last performance or score, and in the work of Mora et al. [PA14] ,the players receive points which are aggregated for a common goal and whose outcomes are shared to all users: unlocking new features and contents. In the proposal of Jăgust et al. in [PA19], students had to solve problems and collect points, and their individual results were presented as a score for the entire class, which had the objective to collect more points than a virus.

Besides community cooperation awareness, there are examples of adaptation that consider group interaction activity to give tailored feedback. The mediator bot in the work of Emmerich et al. [PA5] does interventions triggered by (and built upon) the dialogue interaction between the participants. Similarly, in Padilla-Zea et al. [PA8], an analysis mechanism based on Social Network Analysis is used, focusing on the collaborative process. Then, the adaptation can be automatic or monitored by teachers.

Finally, the gamification design process proposed by Knutas et al. in [PA17] includes the group perspective (heuristics), then the built ruleset, and therefore the generated algorithm is going to consider a community adaptation strategy.

Team building

This section remarks on the team-building approaches that can help leverage the motivation and seek a strategy to keep players engaged. Competence among teams can be an efficient approach. Collaborative software systems and, in particular, Citizen Science projects take advantage of cohesive and balanced working teams, where the individual collaborators have similar proficiency levels. In this sense, it is vital to avoid less proficient players from getting discouraged [33].

Sometimes the team matching is done by the volunteers, and some other times are related to the geographic distribution, but this can lead to an uneven team configuration making the best teams unreachable. Uneven teams configuration may cause the members of less proficient teams to get discouraged but also the members of the best teams to be demotivated. Although the team matching can be manual, automatic, semi-automatic, or free, the teams' configuration must guarantee similar proficiency levels.

On the other hand, multiplayer games usually offer their players different roles to choose from, but not every group composition is possible considering the particular challenge of the game. Indeed, the player choice is often limited, and so the player enjoyment can be reduced.

Team building, among others, is the motivation of Daylamani et al. in [PA13] (and [PA18]) where a recommendation architecture is developed to foster collaboration on massively multiplayer online games by the implementation of features such as team matching, leadership, non-optimally, identity awareness. In this approach, the members' interaction can be improved to make the team more competitive and efficient. So the result of a round may result in changing team structure and formation, i.e., the appointment of a new leader, change of team for a player, or a team's break up. In their architecture, Oulhaci et al. [PA9] have Non-Player Characters that can be used to adapt the game setup to replace the absent or unnecessary playing roles (stakeholders). The work of Padilla-Zea et al. in [PA8] presents a group Sub-system that manages both the design and creation of groups.

The work of Tregel et al. in [PA22] proposes an adaptation of game tasks as an optimization problem over the team's building. Previously, Tregel et al. in [PA16] presented a mechanism to automatically generate a network of playing scenes (abstract interaction patterns), presenting a particular challenge for the team on each interaction. When players individually choose which path to take, it could lead to a split up teams or to get them together.

Adaptability building tools or frameworks

Software engineering theory explains the benefits of applying development guidelines in the software design process, such as the reuse of development effort and quality assurance. In addition to considering the different particular approaches to adaptive gamification in gamified collaborative systems, it is interesting to explore the more general design principles that translate the adaptation strategies and gamification needs into concrete guidelines to assist the design practice. In this section, those primary studies that present some sort of design process or methodology are described (see Table 13). Some works approach adaptability through tools or frameworks to be applied in design stages.

Notably, the work of Knutas et al. [PA17][PA25] proposes an algorithm that can choose context-dependent, gamification tasks for each Hexad user type. Such an algorithm is derived from a ruleset built through their proposed design process, following specific gamification design heuristics.

Similarly, the approach in [PA16] presents a model that allows the generation of a network of collaborative player interaction patterns that uses the patterns' provided information in order to combine them procedurally. The generated network is modified according to metrics that ensure the network's quality and rule out less optimal choices.

On the other hand, the work of Challco et al. in [PA12] notices that the different persuasive strategies -this is, the game design strategies that consist in rules and prescriptions that define how to use the game elements for the changing of attitudes/behaviors- remains in the minds of the developers and therefore the model that allows choosing among the different persuasive strategies attending the behavioral state of the player in each moment is coupled to the system. As a workaround, the authors propose an ontological approach to structure and organize persuasive strategies.

Daylamani et al. come up with a conceptualization that distinguishes the passive personalization, the guided personalization, and the reflective personalization. In their first approach [PA13], they present an architecture where messages are sent to players to encourage engagement and performance triggered by decision trees that do not take player's historical activities into account (passive personalization). In their later work [PA18], this architecture incorporates an agent-based approach for reflective personalization but also to facilitate a scalable and portable approach that enables both player and team profiles to persist across multiple games.

From a learning environment point of view, the approaches of Hassan et al. [PA24] and Padilla-Zea et al. [PA8] present two general architectures to aid in tailored education. The proposed system in [PA24] implements an intelligent bot instructor that provides adaptive feedback to students by indicating the areas in which students are weak. It also presents certain activities to the students, along with appropriate incentives for the user type (self vs. social).

This instructor can be plugged into different e-learning courses. On the other hand, the architecture developed in [PA8] allows the design and adaptation of educational processes supported by video games. This adaptation is carried out through the customization of the educational elements based on what is revealed. It is suggested by the monitoring components of the architecture, which, among other things, observes the events of interest to the user.

This mapping found some articles presenting architectural approaches for learning games, intending to be applicable in multiple scenarios. For example, Ismailović et al. presented the game *We make words* [PA3] as architecture with an extensive learning intelligence which implements a strategy design pattern where the controller can control the learning path by using different strategies. In this same sense, the collaborative conflict management training game developed by Emmerich et al. in [PA5] is implemented over a multi-agent architecture that can be used as an adaptable framework for related collaborative learning scenarios. Finally, the *SINFOR* game [PA9] is a crisis management training that can be applied to different scenarios, using an agent editor (authoring tool).

Lastly, the approach of Yu et al. in [PA7] provides a Drama Manager agent that models the user's preferences on a given branching story graph, to recommend story plots using prefix-based collaborative filtering. This story graph represents a particular story and can be replaced with another, which turns this proposal into a framework itself.

4.4. RQ3: What gamification elements have been used in gamified collaborative systems?

In order to answer this question, two discussion levels are developed. Firstly, the search for each gamification element among the primary studies is done. Since the use of an element does not imply that it is involved in some aspect of adaptation, a more in-depth analysis is carried out to identify which gamification elements are adapted. To facilitate this second task, this article introduces the GEAS (*Gamification Element Adaptation Strategy*) taxonomy.

Table 14: Gamification elements and mechanics by primary studies

Paper	Goals	Personalization	R. Feedback	Visible Status	Unlocking content	Freedom of choice	Freedom to fail	Storyline	Onboarding	Time restriction	Social Engagement	Points	Badges	Levels	LeaaderBoard	Virtual Goods	Avatars
[PA1]	•	•			•											•	
[PA2]	•		•	•													
[PA3]	•	•	•		•			•			•			•			•
[PA4]	•	•	•				•				•	•					•
[PA5]			•			•		•		•	•						•
[PA6]	•		•	•	•	•	•	•		•	•	•			•	•	•
[PA7]								•									
[PA8]											•						
[PA9]	•	•	•		•	•					•						•
[PA10]											•	•	•	•	•		
[PA11]	•		•							•	•			•			
[PA12]	•																
[PA13]	•	•		•		•					•	•	•				
[PA14]	•	•	•	•	•		•			•	•	•	•	•	•		•
[PA15]	•			•	•	•				•	•	•					
[PA16]	•																
[PA17]	•		•	•		•											
[PA18]	•	•		•		•					•	•	•				
[PA19]	•			•								•			•		
[PA20]	•		•									•		•		•	
[PA21]			•									•					
[PA22]	•																•
[PA23]														•			
[PA24]	•		•			•					•	•	•	•	•		
[PA25]			•										•				

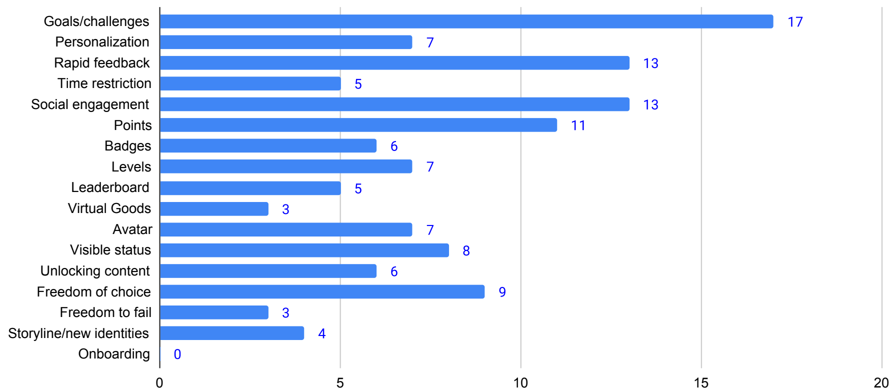

Figure 6: Gamification Elements and Mechanics

In Table 14, the game elements and mechanics are mapped to the primary articles. As it is shown, the most used elements are the *goals/challenges* in the first place, followed by *Rapid Feedback* and *Social Engagement* elements. In third and fourth place are *Points* and *Freedom of choice* elements, with 11 and 9 occurrences, respectively.

The other gamification elements were found similarly distributed (among one to eight articles). Figure 6 is a bar chart that depicts this graphically. As expected, the Social Engagement is a featured item given the articles' collaboration aspect in this work's search results.

Also, an analysis of when (and how) the gamification elements are adapted was done. To this aim, the GEAS (*Gamification Element Adaptation Strategy*) taxonomy is proposed, which is shown in Figure 7. It describes two main adaptation strategies of game elements that have been found. On the one hand, the adaptation approach can apply (or recommend) at different moments, different gamification elements depending on the estimated user preferences. This strategy has been called *Full Gamification Element (GE) adaptation*. Examples of this type of adaptation are Feyisetan et al. [PA10], where the adaptation is based on a predictive model for estimating the most appropriate gamification element

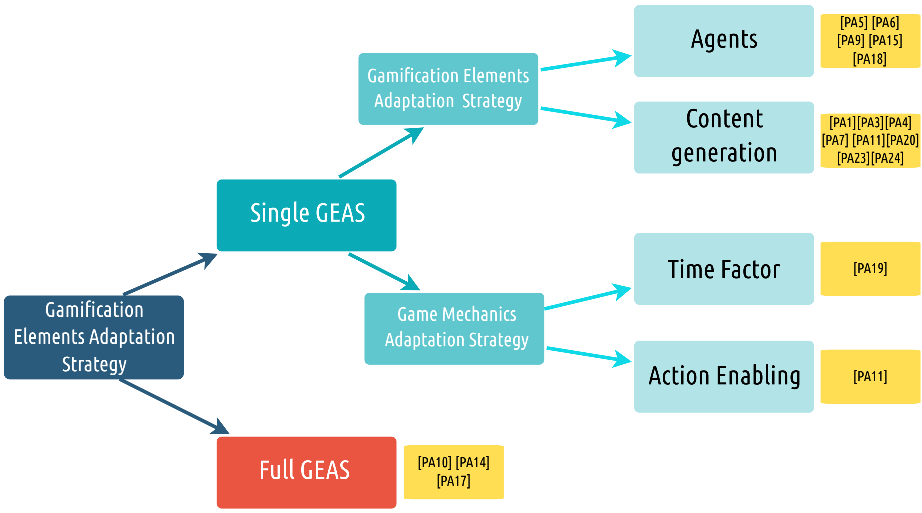

Figure 7: GEAS taxonomy

based on the user's previous reaction to incentives and contribution. Then, Mora et al. [PA14], where the proposal of exercises is based on the cognitive domains of user status, previous user choices and user assessment; and Knutas et al. [PA17], where the users are presented to tailored context-dependent gamification tasks computed by a ruleset derived algorithm.

On the other hand, the adaptation can be done by adjusting some features or traits of the gamification elements according to the player's performance or behavior, but always over the same gamification element or mechanic. These cases are called *single gamification element adaptation*, and it can also be subdivided into two more specific ones: *game elements adaptation*, and *gamification mechanics adaptation*. These sub-classes and others are defined in this section, while are graphically depicted in Figure 7.

The *gamification elements adaptation* is the set of adaptations where the change is applied in the behavior or characteristic of a specific gamification element. Several articles tackle the *adaptation in agent's behavior*, by including a game agent that provides appropriate assistance both on the individual and team level [PA5][PA6][PA18], the virtual representation of some roles [PA9], or

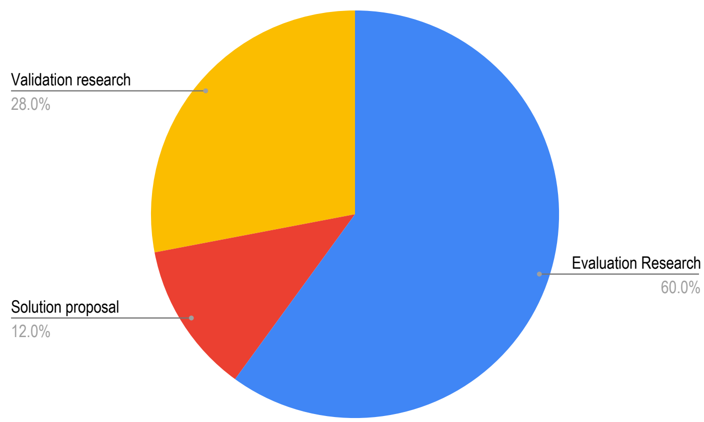

Figure 8: Research Methods

non-player characters [PA15].

Other articles approach adaptation through the *adaptive content generation*. Examples of this content are graphical, like new weapons in a galactic arms race [PA1], new jigsaw pieces in [PA11], additional obstacles in [PA4] and [PA20]; learn tasks or questions using the mistaken personal items of the player and a representation of a learning path [PA3][PA23]; adaptive feedback [PA24]; and plot generation through collaborative filtering [PA7].

The *mechanic's adaptation*, following the MDA framework [25] criteria, is an adaptation of the game that generates a change in the rules, closer to the algorithm level, and mostly related to difficult adaptation. Unlike the previous section, this type of adaptation is made to a particular element. Here we detail the *time factor*, such as the remaining time to achieve a goal (e.g., solving a math problem [PA19]) or the *actions enabling*, for example, to rotate or exchange geometries among players [PA11].

Table 15: Primary study by research methods

Approach	**Articles**
Evaluation Research	[PA1][PA3][PA5][PA6][PA7][PA9][PA10][PA11][PA13][PA15] [PA18][PA19][PA20][PA21][PA23][PA24]
Solution Proposal	[PA8][PA12][PA14][PA16][PA17][PA25]
Validation Research	[PA2][PA4][PA22]

4.5. RQ4: Which research methods have been used in gamified collaborative systems

Figure 8 and Table 15 show the distribution of articles in terms of the research methods (see Table 7). The majority (16 works) are evaluation researches with an empirical test with users. The other primary studies (10 works) are distributed among solution proposals (6 articles) and validation research (3 articles).

When analyzing the assessment variables of the approaches, most of the studies pointed out a performance improvement over time (individual and team scoring [PA3][PA4][PA11][PA13][PA18][PA24], more resolved tasks with better quality [PA19][PA10], number of weapons' evolution [PA1]) through gathered data from real user-game interaction; or did a statistical analysis over the data [PA7].

Some of them are supported by surveys or user skills tests before and after the evaluated approach [PA4][PA5][PA6][PA15][PA20][PA23]. Notably, some of them evaluated the user experience through interviews and opinion surveys [PA6]. The evaluation of the engagement time (like, for instance, the average of playing session's duration) was seen in [PA4] and [PA24].

Finally, simulations are a strategy that was applied to evaluate some of the different approaches [PA7][PA22][PA16].

4.6. RQ5: User Models

Two points of view can be applied to frame the analysis of user modeling. The first point of view is the scope of the model, where three approaches

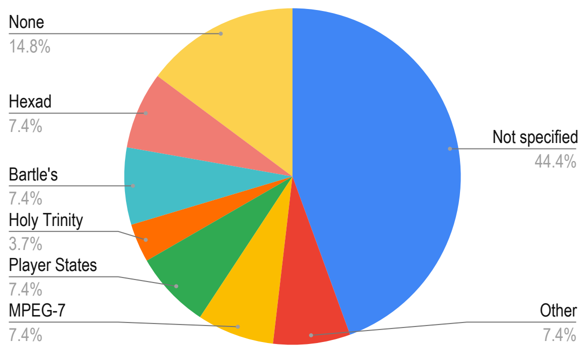

Figure 9: Player Models

Table 16: Primary studies by user model

Model	**Articles**
Not specified	[PA2][PA4][PA5][PA6][PA7][PA8][PA9][PA10]
	[PA11][PA14][PA15][PA20]
None	[PA1][PA19][PA21][PA23]
Other	[PA3][PA24]
Bartle's	[PA12][PA16]
Hexad	[PA17][PA25]
Holy Trinity	[PA22]
MPEG-7, Player States	[PA13][PA18]

have been found, whether it is either standard (those mentioned in Section 3.3), ad-hoc or flexible. The standard Bartle's model was used in [PA12] and [PA16], while the Hexad taxonomy was used in [PA17] and [PA25]. The ad-hoc cases were [PA13] and [PA18]. The MPEG-7 standard is applied to ensure the interoperability of the data. However, these works also propose a model of player states around which adaptation is proposed. The proposal of [PA7] is to build a flexible preference model that aims at extracting the dimensions from the users' ratings instead of constraining to predefined ones.

From the second point of view, which analyzes the versatility, static or dynamic modeling can be distinguished. In the first case, the model is set through an explicit definition of the user's role, which can be understood as a game personalization, normally through a self-definition questionnaire ([PA17] and [PA25]). In the second case, the user preferences are constantly estimated, where the player type is determined by the activities attempted by him/her and time spent on them ([PA3] and [PA24]).

Finally, it is worth highlighting that, in most cases, the model is neither defined nor explicitly specified. This data is shown in Figure 9 and Table 16.

5. Discussion

Collaborative systems are often organized as part of platforms of related projects such as Wikimedia, Github[4], Stack Overflow[5] or, in particular, to citizen science, Zooniverse, and CitSci[6]. These platforms bring together collaborative systems that cover many topics .

In all of them, there is space for any user to find a task of their preference. The Wikimedia organization involves a set of projects designed to develop community knowledge, from content projects like Wikipedia and Wikimedia Commons to technical and development projects like MediaWiki. For its part, the

[4]https://github.com/ accessed on 5th August 2020
[5]https://stackoverflow.com accessed on 5th August 2020
[6]https://www.citsci.org accessed on 5th August 2020

Zooniverse platform nucleates citizen science research projects, from a wide variety of disciplines and topics across the sciences and humanities. Similarly, CitSci gathers a large set of data collecting projects.

The impact of these platforms is possible, thanks to the community of users. Most citizen science projects are made possible by a considerably large group of users, who, despite being located in different parts of the world, build a community through participation, often in more than one project of the platform. These people participate by choosing domains of their interest and types of tasks in which they feel comfortable. It is usual for them to participate in different ways, which makes them part of a community. The community of these collaborative systems platforms can be understood as a **multi-level community**, where coexisting the communities around the specific projects and the platform's community. Also, a specific project could include more fine-grained communities, like the old letters transcription project Shakespeare's World[7] where, in addition to the research specific goals, a group of members gathered in the cooking recipes collection community in the project forum.

Within this collaborative system platform, player profiles are more complex and interesting, taking into account explicit and implicit player choices, behavior and playing style, and their ways of interacting with other individuals. Since participation in the platform can occur through different projects, it makes sense to model the player profile in a cross-community way to extrapolate the player's characterization, behavior, and preferences. Besides, a multi-level community model can be built to register the teamwork dynamics and the style of collaboration or cooperation. A complex scenario that includes the relationships among projects, communities, and participant's characteristics emerges.

From a systemic point of view, the multi-level communities can be analyzed as a Collaborative Ecosystem. The relationships and actions established in the multi-level communities can be valued, such as the governance model, life cycles, and specific collaborative dynamics. Therefore, new adaptive gamification

[7] https://www.zooniverse.org/projects/zooniverse/shakespeares-world/

challenges in collaborative ecosystems appear. What does it mean to build collaborative ecosystems adaptive gamification? In this article, we discussed different dimensions, such as personalization, difficulty adaptation, or storytelling adaptation. All of them are based on the user's previous behavior (alone or group) within the specific context of a project. Relating the user behavior with their presence in a collaborative ecosystem increases the amount of users' data significantly, allowing the inclusion of artificial intelligence approaches. For example, the work of machine learning applied to communities[34, 35, 36].

6. Conclusions

This article systematically analyzed a body of literature examining gamification in collaborative software systems in terms of how the adaptation in gamification has been implemented. The results evidence the lack of research literature in the study of adapting gamification in the field of collaborative systems. Taking into account the underlying cultural diversity in those projects, the adaptability of gamification design and strategies is a promissory research field.

The analysis of the results for the first research question shows that the existing research on gamification applied to collaborative systems in terms of personalization is preliminary or even immature since more than the fifty percent of primary studies did not take advantage of the possibility of incorporating personalization as an appropriation strategy or was not specified.

Regarding the different aspects of adaptation, this systematic mapping explored different dimensions of analysis proposed by Göbel [13], such as difficulty adaptation, storytelling adaptation, and Kickmeier-Rust criteria. Additionally, in this article, new adaptation categories were proposed. These categories include community-based adaptation, team building, and frameworks or tools to facilitate the design of the adaptation in gamification.

In the use of gamification elements analysis, as was expected, the goals/challenges and points were the most used. However, the adaptation was applied to specific ones. Thus, the Gamification Element Adaptation taxonomy was introduced. Agents and content generation were the adaptations with the most cases. An extension and in-depth analysis of this taxonomy are considered as a line in further work.

Pointing at the fourth research question (Research Method), the most used method was evaluation researches with an empirical test with users.

The user modeling analysis was framed from two points of view, considering the scope of the model (standard, ad-hoc or flexible) and the versatility (dynamic vs. static). Also, it was found that in most of the cases, the model is neither defined nor explicitly specified.

Finally, this mapping evidences that the aspect that deserves further research is the adaptability taking into account the community, focusing on features that have not yet been worked on, such as cultural diversity, gender, and multiplicity of knowledge. Also, it is interesting to develop an approach of community modeling in community-aware adaptive gamification.

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Appendix A. Query strings

The search string used for *Scopus* was the detailed in Listing 1, and led to 334 items. The *IEEExplore* database query is described in Listing 2 and led to 118 items. Listing 4 shows the *ACM* database query which led to 101 hits. In *Springer* database, the Computer Science discipline was applied and the following disciplines were chosen: Computers and Society, Information Storage and Retrieval, Information Systems Applications (incl. Internet) and User Interfaces and Human Computer Interaction. Additionally, the option *Include*

```
( TITLE-ABS-KEY ( adaptation OR adaptive OR adaptability OR
    adaptivity OR customization OR customizing OR
    personalization OR personalize OR evolutionary ) AND
    TITLE-ABS-KEY ( gamification OR gamifying OR gamify OR "
    gameful design" OR gamefulness OR funware OR "serious
    games" OR game OR gamified ) AND TITLE-ABS-KEY (
    collaborative OR crowdsourcing OR "Citizen Science" OR "
    Community Science" OR "people power" OR groupware OR
    cooperative ) ) AND ( LIMIT-TO ( SUBJAREA , "COMP" ) ) AND
     ( LIMIT-TO ( DOCTYPE , "cp" ) OR LIMIT-TO ( DOCTYPE , "ar"
     ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) ) AND (
    EXCLUDE ( EXACTKEYWORD , "Game Theory" ) ) AND ( LIMIT-TO (
    PUBYEAR , 2019 ) OR LIMIT-TO ( PUBYEAR , 2018 ) OR LIMIT-
    TO ( PUBYEAR , 2017 ) OR LIMIT-TO ( PUBYEAR , 2016 ) OR
    LIMIT-TO ( PUBYEAR , 2015 ) OR LIMIT-TO ( PUBYEAR , 2014 )
     OR LIMIT-TO ( PUBYEAR , 2013 ) OR LIMIT-TO ( PUBYEAR ,
    2012 ) OR LIMIT-TO ( PUBYEAR , 2011 ) OR LIMIT-TO (
    PUBYEAR , 2010 ) OR LIMIT-TO ( PUBYEAR , 2009 ) ) AND (
    EXCLUDE ( EXACTKEYWORD , "Wireless Networks" ) OR EXCLUDE (
    EXACTKEYWORD , "Cognitive Radio" ) OR EXCLUDE ( EXACTKEYWORD
     , "Wireless Telecommunication Systems" ) OR EXCLUDE (
    EXACTKEYWORD , "Cognitive Radio Network" ) OR EXCLUDE (
    EXACTKEYWORD , "Prisoner's Dilemma Game" ) OR EXCLUDE (
    EXACTKEYWORD , "Prisoner's Dilemma" ) OR EXCLUDE (
    EXACTKEYWORD , "Radio" ) OR EXCLUDE ( EXACTKEYWORD , "
    Iterated Prisoner's Dilemma" ) OR EXCLUDE ( EXACTKEYWORD , "
    Radio Systems" ) )
```

Listing 1: Scopus search string.

```
( adaptation OR adaptive OR adaptability OR adaptivity OR
    customization OR customizing OR personalization OR
    personalize OR evolutionary
) AND( gamification OR gamifying OR gamify OR "gameful design
    " OR gamefulness OR funware OR "serious games" OR game OR
     gamified
) AND( collaborative OR crowdsourcing OR "Citizen Science" OR "
    Community Science" OR "people power" OR groupware )
```

Listing 2: IEEExplore search string.

```
(adaptation OR adaptive OR adaptability OR adaptivity OR
    customization OR customizing OR personalization OR
    personalize OR evolutionary )
AND
(gamification OR gamifying OR gamify OR "gameful design" OR
    gamefulness OR funware OR "serious games" OR gamified)
AND
(collaborative OR crowdsourcing OR "Citizen Science" OR "
    Community Science" OR "people power" OR groupware)
```

Listing 3: Springer search string.

```
[[[Publication Title: adaptation] OR [Publication Title: adaptive] OR [Publication
     Title: adaptability] OR [Publication Title: adaptivity] OR [Publication
    Title: customization] OR [Publication Title: customizing] OR [Publication
    Title: personalization] OR [Publication Title: personalize] OR [Publication
    Title: evolutionary]]
AND
[[Publication Title: gamification] OR [Publication Title: gamifying] OR [
    Publication Title: gamify] OR [Publication Title: "gameful design"] OR [
    Publication Title: gamefulness] OR [Publication Title: funware] OR [
    Publication Title: "serious games"] OR [Publication Title: game] OR [
    Publication Title: gamified]]
AND
[[Publication Title: collaborative] OR [Publication Title: crowdsourcing] OR [
    Publication Title: "citizen science"] OR [Publication Title: "community
    science"] OR [Publication Title: "people power"] OR [Publication Title:
    groupware]]
]
OR [[
[Abstract: adaptation] OR [Abstract: adaptive] OR [Abstract: adaptability] OR [
    Abstract: adaptivity] OR [Abstract: customization] OR [Abstract: customizing]
    OR [Abstract: personalization] OR [Abstract: personalize] OR [Abstract:
    evolutionary]]
AND
[[Abstract: gamification] OR [Abstract: gamifying] OR [Abstract: gamify] OR [
    Abstract: "gameful design"] OR [Abstract: gamefulness] OR [Abstract: funware]
    OR [Abstract: "serious games"] OR [Abstract: game] OR [Abstract: gamified]]
AND
[[Abstract: collaborative] OR [Abstract: crowdsourcing] OR [Abstract: "citizen
    science"] OR [Abstract: "community science"] OR [Abstract: "people power"] OR [
    Abstract: groupware]]] OR [[
[Keywords: adaptation] OR [Keywords: adaptive] OR [Keywords: adaptability] OR [
    Keywords: adaptivity] OR [Keywords: customization] OR [Keywords: customizing]
     OR [Keywords: personalization] OR [Keywords: personalize] OR [Keywords:
    evolutionary]]
AND
[[Keywords: gamification] OR [Keywords: gamifying] OR [Keywords: gamify] OR [
    Keywords: "gameful design"] OR [Keywords: gamefulness] OR [Keywords: funware]
     OR [Keywords: "serious games"] OR [Keywords: game] OR [Keywords: gamified]]
AND
[[Keywords: collaborative] OR [Keywords: crowdsourcing] OR [Keywords: "citizen
    science"] OR [Keywords: "community science"] OR [Keywords: "people power"]
    OR [Keywords: groupware]]]
AND
[Publication Date: (01/01/2009 TO 12/31/2019)]
```

Listing 4: ACM search string.

Preview-Only content was set. This process led to 197 items, and the query text is shown in Listing 3