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On Gamifying an Existing Healthcare System: Method, Conceptual Model and Evaluation

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***Abstract*—Software gamification aims at engaging users with software system features. User engagement is promoted via a gamification model that associates game elements (e.g., points) and rules (e.g., ranking policy) with each feature. Gamification has been increasingly explored in certain healthcare domains, such as chronic disease management and physical activity. However, there are currently two important literature gaps. First, certain healthcare domains in which user engagement is even more critical, such as the prevention of mosquito-transmitted diseases, have not systematically explored gamification yet. Healthcare systems of this domain largely depend on the wide engagement of the population, health professionals and authorities. Second, gamification is often introduced in existing systems developed without gamification in mind. Current methods are quite limited to support this task. In this paper, we report our experience while defining, incorporating, and evaluating a gamification model of an existing healthcare system called VazaZika. VazaZika is intended to assist the prevention of mosquito-transmitted diseases in economically emerging countries. We present and discuss the application of a method, adapted from a previous study, to support the design and incorporation of a gamification model in existing systems (VazaZika, in our case). We also present the resulting conceptual model based on 12 game elements and 16 rules. We evaluate this model with 20 users in terms of ease of use and potential for user engagement. Our results suggest that our conceptual model has resulted in an easy-to-use system with the potential of truly engaging users with critical healthcare-related features. We expect the method and its resulting model can be further reused and adapted to similar healthcare systems.**

***Keywords*-gamification; healthcare system; method; conceptual model; evaluation;**

I. Introduction

Gamification is defined as the use of game elements and rules in non-game contexts [1]. Software gamification aims at making users engage with the key features of a software system [1]. A conceptual gamification model defines game elements (e.g., points) and rules (e.g., ranking policy) and associates them with the system's features [1] [2]. Gamifying a software system consists of defining such a conceptual model and incorporating it into that system [2]. Gamification models are intended to make the use of a system motivating, enjoyable, and easy, thereby promoting user engagement.

User engagement is particularly important in certain healthcare domains [3]. It has been considerably explored in chronic disease management [4] [5], but poorly explored in some domains such as the prevention of mosquito-transmitted diseases [6]. Wide and active participation of people in emerging countries is essential to prevent mosquito-transmitted diseases like Dengue fever and Zika [7]. Healthcare systems of this domain also largely depend on the wide engagement of health agents and authorities [7]. In this healthcare domain, like in others, gamification commonly has to be introduced in existing systems, i.e., those developed without gamification in mind.

There is a limited software engineering support to define a conceptual model and incorporate it in existing healthcare systems [8]. Methods for guiding development teams on defining and incorporating game elements and rules into an existing system are scarce. Current methods tend to support requirements elicitation and design of gamified systems from scratch [9] [10]. However, these methods are not tailored to situations where gamification needs to be integrated in an existing system. Moreover, many of the resulting gamification models for healthcare domains are not explicitly defined, thereby making their reuse quite challenging.

This paper reports our experience on defining, incorporating, and evaluating a gamification model in an existing healthcare system called VazaZika [6]. VazaZika is intended to assist the prevention of mosquito-transmitted diseases like Zika in economically emerging countries. We present and discuss the application of a method aimed to support the design and incorporation of a gamification model in existing systems (VazaZika, in our case). Our method adapts a previous work [9] that helps gamifying systems from scratch. This paper also presents our resulting gamification model. The model was built for: (1) addressing the need for constantly reporting mosquito breeding sites, (2) promoting the collaborative work of citizens towards the disease prevention,

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and (3) promoting a fruitful competition among citizens. Healthcare systems that share these gamification goals could benefit from reusing our model. The gamification model consists of 12 game elements and 16 rules, also inspired by successful gamified systems such as Waze.

We evaluated our model with 20 citizens by assessing the VazaZika mobile application under two aspects: ease of use and user engagement. Our study results are promising. At least 55% of citizens found the system is easy to use. A half of citizens have attributed the ease of use to the incorporated game elements and rules. Even with a few bugs found in the gamified system along the experiment: (i) 65% of the citizens considered the system was certainly fun, and (ii) 55% of citizens were strongly motivated to use the system features again. These findings suggest our gamification model has the potential of truly engaging users with critical healthcare-related features. We expect the method and our resulting gamification model have the potential to be further reused and adapted to similar healthcare systems.

II. The Need for Gamifying a Healthcare System

The success of many healthcare systems largely depends on the engagement of users such as health professionals and citizens [6] [7]. Thus, game elements and rules have been explored by existing healthcare systems in a wide range of domains [3]. Examples of game elements include points, badges, and challenges. Rules define the interaction of system users and game elements, and examples include policies for ranking users and assigning points to them while exploring using a certain system's feature.

Only a few healthcare systems support the prevention of diseases like Zika [7], which are transmitted by the *Aedes aegypti* mosquito. This mosquito is a global threat that has rapidly spread due to poor basic sanitation plus warm and humid weather [7]. Traditional prevention solutions may not suffice to engage citizens because such engagement with healthcare-related tasks is challenging [3]. Thus, we have proposed VazaDengue [7]: a healthcare system that collects reports of disease cases and mosquito breeding sites. The system also automatically mines posts in social networks, such as Twitter, to collect reports from citizens [11]. Our goal was also to provide real-time monitoring of such reports for public health agents and citizens so that prompt action could be taken to eliminate mosquito breeding sites.

Unfortunately, over three years of system deployment, we observed the decay in the number of new system users, views, and installations [12]. Such decay suggested a lack of continuous user engagement with the system. Thus, public health agents had an insufficient number of reports to cope with disease outbreaks. As a response to the observed lack of user engagement, we decided to use gamification [2] for making VazaDengue enjoyable and motivating, while not making the system more difficult to use. This decision was driven by our major long-term goal of promoting a constant report of mosquito breeding sites. The gamification of VazaDengue resulted in the VazaZika gamified version [6].

III. A Method for Gamifying Existing Systems

The VazaZika gamification is part of a research project performed by Software Engineering and Data Analytics specialists from Brazil and the European Union (EU). The system is developed by five developers, none with experience in gamifying existing systems. We first searched in the literature for methods that could assist them in gamifying our existing system. Unfortunately, we have found a few methods – all aimed to support the gamification of systems from scratch (e.g., [9] and [10]). The lack of methods led us to adapt a previous work [9] that helps gamifying systems from scratch. Figure 1 shows the six method phases, their activities and relationships. The figure relies on the Business Process Model and Notation (BPMN). All phases sum up: ten activities adapted from the existing method; one activity fully reused from that method; and nine new activities necessary to gamify existing systems. We do not describe the *proceed with coding and testing* activity because it depends on the development techniques adopted by companies and developers. We explain the six phases as follows.

A. System Preparation

The first phase aims to discuss on the goals that developers expect to accomplish when gamifying the existing system. A gamification goal is any concrete need for making the system enjoyable and challenging for its users. In the specific case of VazaZika, we have tried to answer questions such as *How do mosquito-borne diseases spread in economically emerging countries like Brazil?*, *How do citizens and public health agents contribute to the disease prevention?*, and *What tasks are critical to the disease prevention and, therefore, should be constantly performed by the citizens?* This phase consists of three activities described as follows.

- **Elicit Gamification Goals** consists of listing what the existing users and potentially new users should expect from the gamified version of the existing system. We recommend the developers to meet internally and promote workshops with existing and new system stakeholders, such as (but not limited to) health authorities, institutions, and the system users. Our experience in gamifying VazaZika has benefited from meetings with health agents [6] and other types of stakeholders.
- **Rank Goals by Priority** consists of ranking the elicited gamification goals by priority. Each software project has particularities. We recommend to define a prioritization criterion. In the VazaZika case, rewarding the reports of mosquito breeding sites had the highest priority. That is because, without these reports, the public health agents cannot prevent the disease outbreaks.

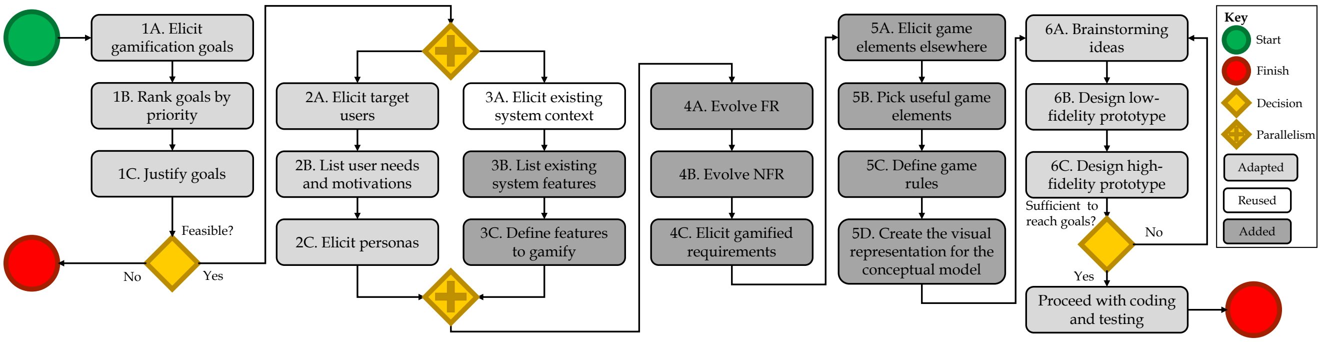

Figure 1. A method for gamifying existing systems

- **Justify Goals** means documenting the rationale behind each goal. A well-documented rationale can help to understand the enjoyability and the effort required to incorporate gamification into the existing system. If the system gamification is sufficiently justified, then the developers can proceed with the next phase. Otherwise, it may be the case that gamifying the existing system is not actually the best solution to leverage the user experience. We recommend the constant support of system stakeholders, as we had from the health authorities [6].

B. *User Analysis*

The second phase aims to characterize the existing system users. While gamifying VazaZika, we aimed to address questions like *What were the VazaDengue users?* This phase also aims at reasoning about additional users that could be interested in the gamified system. In the VazaZika case, we tried to answer questions like *Who would be the potential users of the gamified system?* and *Is there any chance of losing users after the existing system is gamified?* This phase has the three following activities.

- **Elicit Target Users** consists of listing the candidate gamified system users. We recommend the developers to first list the current users of the existing system. Thus, developers can consider the risks of these users leaving the system after gamifying the existing system.
- **Elicit User Needs and Motivation** consists of listing the needs by candidate user. We recommend the developers to meet with the stakeholders and ask them about their practical needs, but also track the motivations behind the user interaction with the existing system.
- **Elicit Personas** consists of summarizing the lists of target users, needs, and motivation into personas [13]. Personas are mechanisms for abstracting user profiles in terms of human characteristics, such as age and professional background. We recommend describing the daily routine by persona aimed to highlight the context in which they would be engaged with the system features.

C. *Context Analysis*

The third phase aims to characterize the context in which the existing system was developed. Context includes the human resources and technologies employed for developing the system. While gamifying VazaZika, we addressed questions like *What development process has guided the VazaDengue development?* and *What technological constraints affected the system development?* Our experience suggests that the clearer the context analysis, the easier is for developers to cope with challenges along with the system gamification. This phase consists of the three following activities.

- **Elicit Existing System Context** consists of documenting any context information, e.g., employed technologies and design decisions. While gamifying VazaZika, an incomplete context elicitation has led to excessive rework. For instance, poor design decisions led to database and web service redesign too many times.
- **Elicit Existing System Features** consists of listing the main features that constitute the existing system. Our experience shows that, especially if the existing system documentation is scarce or outdated, the feature elicitation is essential to perform the next activity.
- **Define Features to Gamify** means selecting the existing system features that should be gamified. We recommend asking the system stakeholders about: (1) system features that succeeded in their purpose without gamification; and (2) system features that failed in their purpose and could be gamified.

D. *Requirements Elicitation*

The fourth phase has the purpose of systematically documenting the functional, non-functional, and gamification-specific requirements of the gamified systems. This phase consists of three activities described as follows.

- **Evolve Functional Requirements (FR)** consists of refining the FR elicited for the existing system. In contrast to eliciting requirements for a non-existing system, there are features that developers should consider before gamifying the system. In the VazaZika case, we have reused the elicited personas for refining the FR. We elicited five FR, e.g., *The citizen can report mosquito breeding sites through text, pictures, and geolocation data*.

- **Evolve Non-functional Requirements (NFR)** means refining the NFR elicited for the existing system. In the VazaZika case, these requirements have significantly changed. For instance, both performance and availability have become critical due to the addition of gamification features. Such addition has increased the number of web requests. We recommend to consider the technological constraints for performing this activity. We elicited six NFR, e.g., *The system must interoperate through a shared communication protocol*.
- **Elicit Gamified Requirements** complements the two previous activities by specifying the gamification-specific requirements. These requirements encompass the features that emerged from the incorporation of game elements and rules into the existing system. We elicited four requirements including *The citizen can perform tasks either alone or as part of a team*.

E. Gamification Design

The fifth phase has the major goal of building the gamification conceptual model to be incorporated into the existing system. For building this conceptual model, developers have to carefully define the game elements and rules they aim to implement in the existing system. During the VazaZika gamification, we have debated questions like *What game elements could help us in leveraging the enjoyability and challenge levels of VazaDengue?*, *How should these game elements interact for realizing our gamification goals?*, and *How the system users should interact with these game elements?* This phase consists of the four following activities.

- **Elicit Game Elements Elsewhere** means searching for game elements to incorporate into the existing system. For gamifying VazaZika, we tabulated the game elements used by 10 successful gamified systems we are familiar with, e.g., Duolingo and Waze. We present more details in [6]. We recommend this activity for developers without experience with gamification.
- **Pick Useful Game Elements** means picking game elements that help to achieve the gamification goals.
- **Define Game Rules** aims to define how the system users and game elements should interact.
- **Create the Visual Representation for the Conceptual Model** aims to document the conceptual model based on the picked game elements and defined game rules. We strongly recommend a careful modeling of the relationships between game elements and rules, so that developers can avoid rework while gamifying a system.

F. Software Design

The sixth phase aims to define the gamified system aesthetics. While gamifying VazaZika, we have tried to answer questions like *What aesthetics elements may be reused from the existing system?* and *What changes should we apply for incorporating game elements into the existing system interface?* This phase has the three following activities.

- **Brainstorming Ideas** aims to promote discussions on the gamified system aesthetics. In VazaZika, we have designed different interfaces for the mobile and the web application. We recommend to list all ideas and ask the stakeholders' opinions about color schemes, layout items, and screen navigation preferences.
- **Design Low-Fidelity Prototypes** consists of elaborating either manual or tool-supported interface drafts. When gamifying a system with many applications, we recommend to design similar drafts that share elements, so that users can easily migrate across applications.
- **Design High-Fidelity Prototypes** consists of drawing high-fidelity interface prototypes. We recommend to validate and refine these prototypes with stakeholders.

IV. Conceptual Model for Healthcare Systems

A recent work [3] summarized 46 studies that propose healthcare systems. More than half (26 out of the 46) of the studies involve gamified systems. The other 20 studies explore serious games, i.e., game-like systems with a serious purpose [2]. Only 15 out of the 26 gamified systems support some sort of disease prevention, but none target mosquito-transmitted diseases as VazaZika does. They aim to combat non-transmissible diseases like diabetes [4] and rheumatoid arthritis [5], for which prevention and control are significantly different from mosquito-transmitted diseases.

Even worse, most of the conceptual gamification models in such studies are not explicitly defined. In any case, they realize gamification goals that VazaZika does not share. If VazaZika aims to promote constant data reports and collaborative prevention tasks, other systems support personal disease management (e.g., [4] [5]). Besides, these models encompass a few game elements (e.g., points and rankings). Thus, we decided to propose our conceptual model in order to guide healthcare systems with similar goals.

Gamification Goals. Via the System Preparation phase (Section III-A), we derived six VazaZika gamification goals sorted by descending priorities as follows. 1) Promote constant report of mosquito breeding sites, so that tracking disease outbreaks and eliminating sites become easier for the health agents. 2) Promote reports in all Brazilian locations. 3) Promote tasks with varied purpose, difficulty, and user engagement. 4) Provide tasks to be performed individually and in teams by citizens, in order to spread the systems' user base. 5) Engage health agents with the elimination of mosquito breeding sites. 6) Leverage the quality of mosquito breeding site reports. The Brazilian public health agents asked us to prioritize the report of mosquito breeding sites, since it guides most of the agents' daily work.

Personas. In the User Analysis phase (Section III-B), we conducted meetings and workshops with the Brazilian public health agents. We then elicited five personas in the VazaZika context. We illustrate two personas as follows. 1) *Laura* is *18 years old*, she *loves playing games*, and she *lives in a community affected by many disease cases.* 2) *Daniel* is *34 years old*, he *got Zika six months ago*, *several mosquito breeding sites have affected his neighborhood*, and he *is concerned about the chance of his children to get Zika too*. Our website [12] presents the full persona list. These personas helped in defining the conceptual model.

Game Elements. We systematically followed our method in order to decided which game elements to incorporate into VazaZika (Section III-E). By analyzing successful gamified systems [6] and the literature [1] [2], we have defined 12 game elements to compose our conceptual model as detailed in [6]. Table I lists all 12 game elements, including popular ones like points and rankings [1]. By rewarding the citizens for reporting and validating mosquito breeding sites, we expect to promote constant report in different regions.

Table I
GAME ELEMENTS INCORPORATED INTO VAZAZIKA

Game Element	Purpose
Avatar: representation of the citizen [2]	Aimed at immersing the citizen into the system, so that the citizen feels part of the system
Badge: special reward assigned to a citizen [1]	Aimed to recognize the citizen skills regarding specific tasks performed through the system
Challenge: set of tasks that share a purpose [1]	Aimed at challenging the citizen to perform important tasks through the system
Comment: text feedback given by a citizen [1]	Aimed at manifesting the citizen opinion about a task
Level: control of the citizen progress [1]	Usually aimed at unlocking new tasks as the citizen accumulates rewards
Notification: feedback on citizen actions [1]	Aimed at alerting the citizen about completed actions and earned rewards
Point: basic reward assigned to a citizen [1]	Aimed at rewarding the citizen after completing tasks through the system
Ranking: a sorted list of citizens [1]	Aimed at promoting a comparison and competition among citizens
Social activity: registry of citizen actions [1]	Aimed at summarizing the actions, e.g., completed tasks, performed by the citizens
Social sharing: action report via social media [1]	Aimed at promoting the system use outside the system, i.e., in external social networks
Team: group of citizens that share a task [1]	Aimed at promoting the collectivism in the realization of tasks through the system
Vote: validation of a completed task [1]	Aimed at confirming or refuting that a task was correctly performed through the system

Game Rules. Table II lists the game rules incorporated by VazaZika. R1, R2, R8, and R13–R16 define how the citizens interact with VazaZika. For instance, the VazaZika citizens earn points after reporting a mosquito breeding site. It aims at acknowledging the citizen so that he feels encouraged to report sites again. The remainder rules define relations between a pair of game elements, which determines how one element affects another. For instance, points assigned to a VazaZika user count on the user ranking. In the table, we inform the gamification goals addressed by game rules.

Table II
GAME RULES AND GOALS THEY HELP IN ADDRESSING

Game Rule	Goals
R1: Citizens can edit their *avatar*, and create new *challenges* and *teams*	3, 4
R2: The citizen can engage with existing *Challenges*, provide *comments* on citizens' actions, perform *social sharing* of his own actions, and *vote* for mosquito breeding sites reported by other citizens	1, 2, 4
R3: Edit *avatar* and create *challenges* and *teams* generate *notifications*	1, 2
R4: *Avatar* editing and the creation of *challenges* and *teams* by citizens update the *social activity*	1, 2, 4
R5: Engaging with either *challenges*, *comments*, *social sharing*, or *voting* updates the *social activity*	1, 2, 4
R6: Engaging with either *challenges*, *comments*, *social sharing*, or *voting* generates *badges*	1, 2, 4
R7: Engaging with either *challenges*, *comments*, *social sharing*, or *voting* generates *notifications*	1, 2, 4
R8: *Notifications* inform the citizen	1
R9: After either engaging a *challenge* or performing *comments*, *social sharing*, and *voting*, *points* are generated	1, 2, 4
R10: *Points* counts control the *ranking* of citizens	1, 2, 4
R11: *Points* of a citizen control his progression along the game *levels*	3, 4
R12: The citizen *level* unlocks specific citizen actions in the system	3, 4
R13: The health agent can edit his *avatar*	5
R14: *Notifications* inform the health agent that a report was updated by the citizen according to the agent's *vote*	1, 3, 5
R15: The health agent can *vote* about the quality of information of the reported mosquito breeding sites	1, 5, 6
R16: The health agent can *comment* about the quality of information of the reported mosquito breeding sites	1, 5, 6

Relationships Between Elements and Rules. The conceptual gamification model aims to summarize the gamification mechanics [2]. The conceptual model guides developers and stakeholders in understanding how the game elements and game rules interrelate in a software system. Figure 2 illustrates the VazaZika gamification model, which incorporates all 12 game elements (Table I) and 16 game rules (Table II) with the purpose of engaging users with healthcare-related tasks, especially for preventing mosquito-transmitted diseases. Continuous arrows represent the relations between the system and their users (SU) and dotted arrows represent the relations between a pair of game elements (EE).

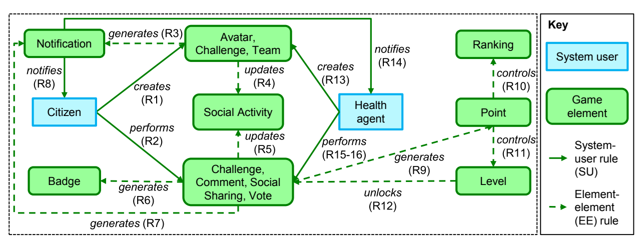

Figure 2. The VazaZika gamification model

We defined a **conceptual model** for guiding the VazaZika healthcare system gamification. Others could extend our model by adding up rules for other stakeholders, such as institutions and health authorities.

We describe the VazaZika user interface in our previous work [6]. VazaZika will be available for Brazilians in the first quarter of 2019 at https://www.vazazika.com.br.

V. Evaluation Study Design

A. Goal and Research Questions

We defined our goal based on a study [14] as follows: *analyze* the conceptual model that supported the gamification of a healthcare system; *for the purpose of* understanding to what extent the model has helped to achieve the system gamification goals; *with respect to* (1) how easy was for citizens to use the system and (2) how engaged these citizens have felt while interacting with the system features; *from the viewpoint of* Brazilian citizens with varied background; and *in the context of* VazaZika healthcare system. We defined three research questions ($\mathbf{RQ}_s$) as follows.

$\mathbf{RQ}_1$**:** *How easy was it for the citizen to use the gamified system?* – We aim to understand whether the incorporation of game elements and rules into the system has contributed for the citizens to use VazaZika. It may be the case that certain game elements hinder the system usage, even though they make the system enjoyable and challenging. These cases would be opportunities for refining our conceptual model and, therefore, adapting it to the user needs.

$\mathbf{RQ}_2$**:** *How engaged was the citizen in using the gamified system?* – We aim to capture whether the game elements and rules incorporated by VazaZika help promote a constant report and validation of mosquito breeding sites. A poor citizen engagement implies a defect in the conceptual model and a need for refinement. In this work, we measure the user engagement by capturing the citizen perception through a closed form question, in a five-point Likert scale.

$\mathbf{RQ}_3$**:** *What is the correlation between ease of use and user engagement for the gamified system?* – We aim to understand if there is any correlation between the ease of use and the user engagement provided by our conceptual model. It might be the case that, the harder it is to use the system, the lower is the user engagement with the system feature. In this case, it would be necessary to refine our model in order to make it easier while enjoyable and challenging.

B. Study Phases and Artifacts

Phase 1: Prepare for the Evaluation. Through the *Consent Form*, **Step 1** consisted of collecting the participant permission to anonymously collect his experiment data. **Step 2** aimed to collect the participant background, e.g., age and education level, via the *Participant Characterization Form*. All participants were asked to use their mobile devices for installing and using the VazaZika mobile application. **Step 3** aimed at instructing in the experiment procedures: 10 minutes for explaining the experiment artifacts and 5 minutes for answering general questions about the experiment.

Phase 2: Run the Activities. We have distributed the *List of Experiment Activities* to all participants before performing Steps 4 to 6. We defined three activities that encapsulate a disjoint set of system features. Two out of three activities are individual and one has to be performed by participants collaboratively. We also distributed the *Activity Experiment Form* composed of open and closed questions. The latter rely on five-point Likert scales. Each form should be filled right after completing an activity. **Steps 4, 5, and 6** were designed to perform Activities 1 to 3 in this order (Section V-C describes the environment settings).

Phase 3: Finish the Evaluation. Step 7 aimed at collecting data about the participant's experience with the experiment via the *Follow-up Form*. This form was distributed for each participant after all participants have completed Activity 3. All artifacts are available in our website [12].

C. Participant Characterization and Environment Settings

The participants have a diverse education level. 55% hold a BSc degree, 40% hold a high school degree, and 5% hold a postgraduate degree. The participant's age ranges from 19 to 28 years (average equals 23.15 years). On average, participants spend 29 hours a week using mobile devices.

We defined three experiment activities. 1) Participants create and edit their avatars individually. 2) Participants engage with a challenge in order to report mosquito breeding sites collaboratively. 3) Participants validate the mosquito breeding sites reported by colleagues individually. We adopted a crossover study design [14] aimed to mitigate a particular threats to the study validity: the low number of participants and the dependency between activities. The Activity 3 input comes from Activity 2 and participants can provide biased validations for reports provided by their colleagues in the same experiment environment. Table III shows the study configuration. E1 and E2 are geographically different environments in which we distributed artificial mosquito breeding sites to be found, reported, and validated.

Table III
CROSSOVER STUDY DESIGN CONFIGURATION

Act.	Elements	Rules	Participants E1	E2
1	Avatar, notification, social activity	R1, R3-4	All	-
2	Badge, challenge, level, notification, point, ranking, social activity, team	R2, R4-7, R9-10, R12	10	10
3	Badge, comment, level, notification, point, ranking, social sharing, vote	R2, R6, R9-10	10	10

VI. Evaluation Results

About $\mathbf{RQ}_1$**.** After performing each experiment activity (Activ. 1 to 3), we asked the participants to indicate how much they agree with the following sentence: *I found it easy to perform this activity*. Table IV presents our study results regarding $\mathbf{RQ}_1$. The second to fourth columns present the percentages for the VazaZika ease of use, according to the responses of the 20 participants. Considering both *Strongly agree* and *Agree*, we observed that at least 55% of participants found easy to perform the experiment tasks. Additionally, only a few participants (5% at most by activity) found very hard to perform the experiment activities.

Table IV
STUDY RESULTS

Perception	Ease to Use (%)				Fun (%)				Motivation (%)			
	Activ. 1	Activ. 2	Activ. 3	All	Activ. 1	Activ. 2	Activ. 3	All	Activ. 1	Activ. 2	Activ. 3	All
Strongly agree	**50%**	5%	25%	27%	15%	30%	10%	18%	5%	25%	5%	12%
Agree	40%	**50%**	**35%**	**42%**	15%	**35%**	**35%**	28%	20%	30%	25%	25%
Neutral	0%	15%	30%	15%	**55%**	20%	30%	**35%**	**60%**	**35%**	30%	**42%**
Disagree	5%	25%	5%	12%	10%	15%	25%	17%	15%	0%	**35%**	17%
Strongly disagree	5%	5%	5%	5%	5%	0%	0%	2%	0%	10%	5%	5%

We asked the participants to justify their perception on the VazaZika ease of use. About 45% of participants associated game elements incorporated by the system with the ease of use. The mentioned elements are vote and social sharing. This result is expected because both game elements are explicit in the VazaZika interface, and the users can interact with them directly through the system, contrary to subtle game elements like comments. Differently from ranking and points, which are perceived after a user action performs in the system. Regarding the participants that mentioned game elements, 78% have found (very) easy to use VazaZika.

*I found the system easy to use, especially because the **voting** feature is easy to use* – Participant 10 about votes

*I found it easy to **share** my actions via social networks [...]* – Participant 11 about social sharing

About RQ$_2$. We assessed user engagement by the lens of fun and motivation. We asked the participants how much they agree with this sentence: *I found it fun to perform this activity*. The 5th to 7th columns of Table IV present the percentages of fun. By considering both *Strongly agree* and *Agree*, up to 65% of participants found fun to perform the activities. However, most participants (55%) stayed in the borderline for Activity 1. This observation is expected as Activity 1 is too simple. Fortunately, only a few participants (5% at most) had no fun in performing some activity.

We also asked the participant to indicate how much they agree with this sentence: *I felt motivated to perform this activity again*. The eighth, ninth, and tenth columns of Table IV present the percentages for the participant motivation. By considering both *Strongly agree* and *agree*, we observed that up to 65% of participants felt motivated to perform the activities again. Most participants (60%) stayed in the borderline for Activity 1. More critically, we have found that 40% of participants did not feel motivated to repeat Activity 3 (by considering both *Disagree* and *Strongly disagree*). In this case, the reason for such a negative motivation can be justified by a software bug found along the experiment run. This bug has affected some users and hindered the validation of reports. We are currently working on the bug fix.

About RQ$_3$. We assessed the user engagement by fun and motivation in order to address **RQ$_3$**. We hypothesize that **HA$_1$:** There is a strong correlation between ease of use and fun. The null hypothesis is **HA$_0$:** There is no strong correlation between ease of use and fun. Additionally, we hypothesize that **HB$_1$:** There is a strong correlation between ease of use and motivation. The null hypothesis is **HB$_0$:** There is no strong correlation between ease of use and motivation. We have applied the Shapiro-Wilk test [15] to assess our data distributions. We have confirmed that our data is not normally distributed. Thus we decided to compute the Spearman's rank correlation coefficient [14]. We considered a confidence interval of 95% (p-value < 0.05).

As a result, we obtained a p-value < 0.05 for Activities 2 and 3. Thus, the computed correlation has statistical significance for both activities. Table V presents the correlation results. The first column lists the experiment activities. The second column presents the correlation between ease of use and fun. The third column presents the correlation between ease of use and motivation. We have categorized the correlation values according to a previous work [16].

Table V
SPEARMAN'S RANK CORRELATION RESULTS

Activ.	Correlation(Ease, Fun)		Correlation(Ease, Motivation)	
	Correlation	Category	Correlation	Category
1	0.3487773	Weak	-0.0748679	Weak
2	0.6512982	Strong	0.7672592	Strong
3	0.6454658	Strong	0.5762920	Moderate
All	**0.370049**	**Weak**	**0.2957552**	**Weak**

Our results confirm HA$_1$ for Activities 2 and 3. Thus, reporting and validating reports of mosquito breeding sites are both easy and fun to perform. Conversely, we reject HA$_1$ (and confirm HA$_0$) for Activity 1. It indicates an opportunity for making funnier and more challenging the avatar feature. We also confirmed HB$_1$ for Activity 2, i.e., the report feature. This observation is relevant because the report feature is essential to support disease prevention. Unfortunately, we rejected HB$_1$ (and confirmed HB$_0$) for Activities 1 and 3. We point out the moderate correlation between ease of use and motivation for Activity 3. This observation suggests that the validation feature requires just a few improvements.

We **empirically evaluated** our conceptual model via the VazaZika mobile application. Our results suggest that the model resulted in an easy-to-use system that engages users with critical healthcare-related features.

VII. THREATS TO VALIDITY

Construct Validity. We designed our study artifacts (e.g., study protocol and forms) prior to the experiment run. Thus, we expected to avoid changing the study procedures as we analyze the experimental data. We wrote and validated the forms in pairs in various review rounds. We adopted a crossover study design [14] aimed at maximizing the citizen participation in the experiment. We designed experiment activities that involved all elements and rules of our model.

Internal and External Validity. We followed strict procedures for running the experiment with citizens. We collected their background prior to the experiment execution. We also trained two instructors for conducting the experiment in different environments. The participants of one environment were physically isolated from the other participants aimed at reducing biases. We trained all participants on the study procedures and addressed their concerns. Our set of participants is limited but diversified as shown in our website [12].

Conclusion Validity. We carefully performed the quantitative data analysis. We tabulated and validated all extracted data in a pair. Thus, we expected to avoid missing and incorrect data. The analysis followed well-known guidelines of descriptive data analysis [14]. We computed the data distribution before applying the correlation tests. Thus, we aimed to mitigate statistical analysis biases.

VIII. Final Remarks

We introduced a gamification method adopted from a previous work [9] to key needs of gamifying an existing system. We also built a conceptual gamification model that was positively perceived by potential system users. Although the successful VazaZika gamification suggests the method effectiveness, we plan to perform a more systematic assessment by applying it to develop other healthcare systems: one in the same domain of mosquito-transmitted diseases, other in other healthcare domains. This systematic assessment will enable us to capture opportunities for improving the method. Given the positive results, we expect our model will guide the gamification of similar healthcare systems (e.g., [17]).

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