Gamification to support crowdsourcing and participatory mapping for signaling and spatialization of Covid-19 transmission predictors

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Abstract. *The active involvement of the population in health initiatives is crucial to combating Covid-19, especially in vulnerable urban communities. In these areas, the absence of detailed geographic data is a challenge for effective spatial interventions. This study proposes a solution that implements a gamification design model to support participation in disease combat initiatives through participatory mapping and crowdsourcing approaches. The UTAUT was employed to identify conditions influencing the solution's acceptance. A study involving 20 young individuals from a suburban community in Brazil demonstrated that "effort expectancy" and "social influence" significantly impact the behavioral intention to use the platform.*

1. Introduction

Crowdsourcing involves the collaborative generation of ideas, content, and artifacts, typically employing methods to collect information or various resources from a crowd of individuals with the aim of meeting specific objectives or carrying out a particular project [de Freitas and Ewerton 2019].The crowdsourcing approach can be employed for the organization and coordination of movements, political actions, and proposals, as well as to enable coordinated actions among individuals, organizations, and networks, becoming a common practice in the public sphere. It is essential to emphasize that the primary means responsible for facilitating crowdsourcing is the internet [Brabham 2013].

The potential of mobile devices to amplify this problem-solving model is evident. It has been observed that through these devices, contributions can be made easier and more ubiquitous [Chatzimilioudis et al. 2012]. Thus, the sensoring capabilities present in mobile devices favor both the crowdsourcing and participatory mapping approaches. Literature studies highlight that data collected through crowdsourcing are relevant for dealing with, responding to, and mitigating the damages caused by epidemics, more recently, the Covid-19 pandemic [Leung and Leung 2020]. The absence of spatial data to support spatial responses during this period of health emergency is evident, especially in vulnerable urban communities.

Participatory mapping is a branch focused on mapping with social application, utilizing techniques traditionally employed by geographers and individuals within the context of the studied area [Araújo et al. 2017]. Participatory mapping also emerges as an approach that contributes to various areas of knowledge, being employed in projects within the field of epidemiology in various countries, highlighting the dissemination of the term "participatory epidemiology". Participatory epidemiology was initially developed by small-scale community health programs and later consolidated and reapplied by international disease control projects [Jost et al. 2007]. Studies have indicated that game strategies and mechanics can be combined with crowdsourcing and participatory mapping for epidemic control [Oliveira et al. 2016].

Gamification corresponds to the use of game mechanics for solving practical problems or as a means of engaging a specific audience [Ulbricht and Fadel 2014]. It involves applying game elements to activities not directly related to the gaming domain [Heffernan et al. 2016]. Gamification can be explored in the field of health, providing significant benefits for promoting healthy behaviors and habits [Heffernan et al. 2016, Edwards et al. 2016]. Additionally, there is potential for implementing gamified environments with participatory approaches to combat epidemics [OLIVEIRA 2015].

In this work, we present a solution that uses the GAFCC gamification design model to support participatory mapping and crowdsourcing approaches for obtaining spatially distributed indications regarding the presence of Covid-19 transmission predictors in a participatory manner. Additionally, it provides real-time notifications about users approaching areas previously identified as having the potential risk of Covid-19 transmission. This study was guided by the following research question: "Can the implementation of a gamification design model assist the use of participatory mapping and crowdsourcing approaches in practices aimed at combating Covid-19 in vulnerable communities?"

2. Related works

Even with limited resources and a deficient healthcare system, India launched the country's first participatory disease surveillance initiative through the Aarogya Setu app [Garg et al. 2020b]. The Aarogya Setu app aims to track individuals infected with Covid-19. Using device location data and Bluetooth to detect the proximity of infected individuals, the app also features a chatbot providing health ministry updates on the disease. The app's usage by the population is optional.

In Israel, a system named Hashomer was developed as an enhancement to the official app published by the country's Ministry of Health, HaMagen [Pinkas and Ronen 2021]. To trace contact with infected individuals, it utilizes the same principles described earlier: through the use of GPS and Bluetooth. However, Hashomer focuses on user privacy and data security. In Singapore, the government provided a system for tracking and monitoring contact with confirmed Covid-19 cases, the digital contact tracing system called 'TraceTogether' [Huang et al. 2021]. The studied system consists of a mobile app and a low-energy Bluetooth token, both capable of tracking the user's location and contacts using GPS and Bluetooth.

Upon analyzing the mentioned works, it becomes that contact tracing initiatives are beneficial in addressing infectious diseases like Covid-19. However, due to the privacy policies adopted by Western countries, this methodology is not widely adopted in these countries [Garg et al. 2020a], unlike in Eastern countries where the use of such technologies is, in some cases, mandatory.

Frequently employed as a means of social control during the Covid-19 pandemic, the participatory surveillance approach is explored in various ways across different countries. Therefore, this research did not adopt any practices related to this approach, especially social monitoring. This study is limited solely to the use of crowdsourcing and participatory mapping approaches, with all procedures carried out by participants being optional.

3. Methodology

The research question elucidated in this work is verified through qualitative-quantitative research, of an applied nature. In this way, the research question is addressed through action research methodology. In Figure 1 it is possible to observe the diagram of the action research methodology applied to this study.

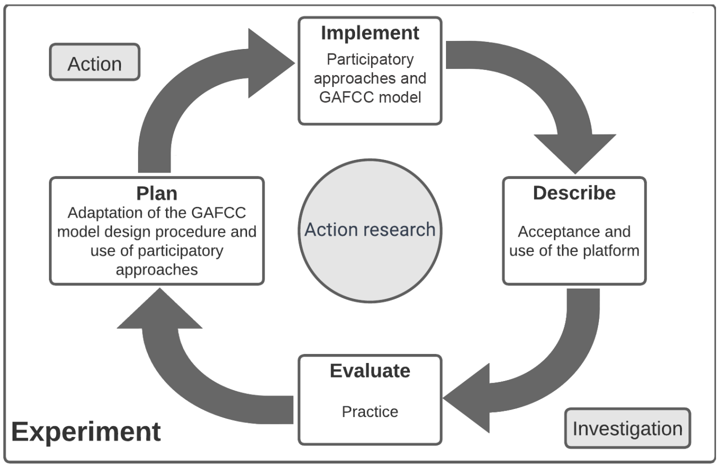

Figure 1. Diagram of the action research methodology applied to this study.

Aimed at solving collective problems, as well as learning for research participants and researchers involved [Picheth et al. 2016], the action research methodology was chosen for its cyclical characteristic, where a change is planned, implemented, described and evaluated to improve your practice [Tripp 2005]. In view of the problem addressed in this study, action research in practical mode is a method that allows us to investigate gamification and participatory approaches of Crowdsoucing and Participatory Mapping in a real scenario, in which the hypothesis raised could be verified and the context addressed really exists.

This research is part of the project ”Building Healthy Communities in Brazilian Urban Slums”, carried out at the Collective Health Institute of the Federal University of Bahia (UFBA). This project was evaluated and approved by a local ethics committee (ISC/UFBA). The partnership enabled to the participants the association of knowledge, attitudes, and practices in relation to the new Coronavirus pandemic. Thus, thanks to the use of participatory approaches proposed in this study, although certain project activities were conducted remotely, participating youth and adolescents had the opportunity to experience the practice and exercise their knowledge through activities provided on the +Lugar platform.

3.1. Unified Theory of Acceptance and Use of Technology (UTAUT)

To evaluate the acceptance and use of the proposed methodology, UTAUT was used. This is a model of acceptance and use of technologies that uses constructs with four moderating conditions (gender, age, experience, and voluntariness), and four determining conditions (performance expectation, effort expectation, social influence, and facilitating conditions). Thus, it is possible to observe the implication of moderating factors in relation to determining factors, as well as determining factors in relation to behavioral intention and usage behavior [Venkatesh et al. 2003].

In the diagram listed in Figure 2 it is possible to observe the association of implications of each moderating condition in relation to the determining factors of UTAUT, as well as the association of implications of determining factors in relation to the intention to use and the behavior of use.

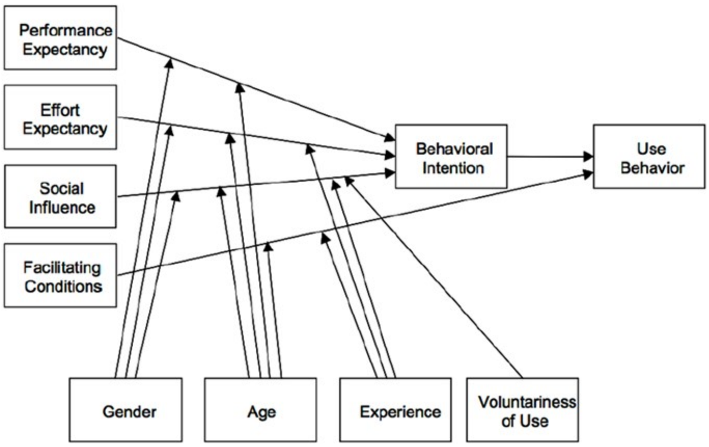

Figure 2. UTAUT Structure (Adapted from [Venkatesh et al. 2003].)

The determining constructs of UTAUT, as well as its impacts on the Behavioral Intention (BI) of young people and adolescents to use the platform, were adjusted in the research model. The relationship between these four constructs and their respective elucidated hypotheses is presented in Table 1.

Table 1. Constructs and Hypotheses.

Determining constructs	Hypotheses
Performance Expectation (PE)	H1: PE has a positive impact on the BI of platform usage.
Effort Expectancy (EE)	H2: EE has a positive impact on the BI of platform usage.
Social Influence (SI)	H3: SI has a positive impact on the BI of platform usage.
Facilitating Conditions (FC)	H4: FC has a positive impact on the BI of platform usage.

***Behavioral Intention (BI)**

4. +Lugar Platform: Covid-19 Version

Developed by a multi-reference team of researchers with support from the Bill and Melinda Gates Foundation and the Medical Research Council (MRC) - UK, the initial version of the +Lugar platform consisted of a multiplatform application. In this way, the platform's primary objective is to promote the engagement and commitment of its users to help improve the environment in which they are inserted, primarily considering collective health and control of zoonoses [Arouca et al. 2019].

Thus, the +Lugar platform provides participatory mapping of zoonoses and their predictors using gamification resources, in addition to having a section designed to cover external projects from different segments that aim at participatory mapping in favor of social contribution [Arouca et al. 2020]. However, although it was designed to use gamification, no framework or model was initially used to support this process.

The Covid-19 version of the +Lugar platform is the product of all the contributions arising from this work to the platform, aggregating all *insights* acquired during the first five stages of the action research carried out. However, due to the chronological flexibility provided by action research, upgrades were carried out after the end of the first cycle. In Figure 3 you can see prints of the Covid-19 version of the platform, which features the contributions arising from this work. This version was structured in two parts, so that one side has a server with an API and a database, and the other has two applications, a hybrid application for mobile devices and a Web application, corresponding to the interface of the client.

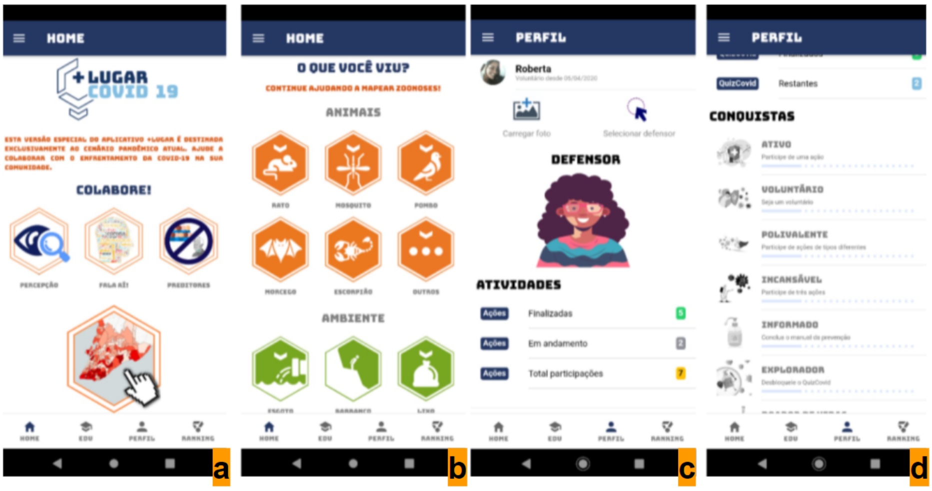

Figure 3. Mobile application of +Lugar platform (Covid-19 version): a) collecting and visualizing data about Covid-19, b) collecting data on zoonoses, c) profile customization, d) gamification and engagement components.

In addition to the spatialization and signaling mechanism of Covid-19 transmission predictors, this work presents contributions to several segments of the platform, among them, the process of creating and implementing avatars through the co-design approach, the improvement of participatory mapping process, the use of crowdsourcing to support social and health demands, and mainly the adaptation of the design and implementation procedure of the GAFCC [Huang and Hew 2018] gamification design model to support the participatory approaches explored in this work.

4.1. GAFCC Model

Originally developed for the scope of education, the GAFCC model employs the synthesis of crucial aspects of the five main motivation theories to design a theory-driven gamification design model. Therefore, the model proposes the use of five elements that contribute to a motivating experience: Goal, Access, Feedback, Challenge, and Collaboration (GAFCC) [Huang and Hew 2018]. The GAFCC model aims to transfigure motivating elements into components such as points, items, badges, and leaderboards.

To ensure alignment of motivation theories, gamification strategies, and instructional objectives, it is recommended that a five-stage gamification design procedure be followed. These five steps of the procedure are: i) examine, ii) decide, iii) combine, iv) launch and v) evaluate. To implement the GAFCC model carried out in this work, small adaptations were made to the gamification design procedure, where the motivating elements were transfigured into game design elements. Thus, new game design elements were implemented in the Covid-19 version of the platform, for example: achievements, ranking, progress bars, and avatars developed through the co-design approach. Figure 4 provides an overview of the adaptation of the design procedure proposed in the GAFCC model, the adaptations are highlighted in gray.

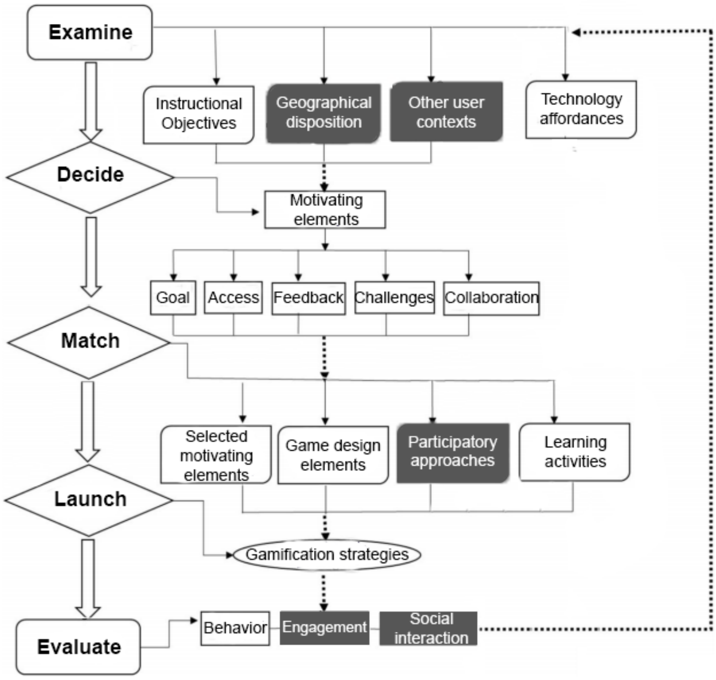

Figure 4. Overview of adaptation of design process steps (Adapted from [Huang and Hew 2018].)

4.2. Spatialization and signaling of Covid-19 transmission predictors

Due to the need for collective effort to mitigate damage and confront the Covid-19 pandemic [Wolf et al. 2020], a specific mechanism was implemented in the +Lugar platform (Covid-19 version) to promote the mapping of disease transmission predictors. For instance, this includes points of congregation, absence of the use of Personal Protective Equipment (PPE), and Collective Protection Equipment (CPE) in public places. It also facilitates signaling the proximity between these reported areas and the platform users.

The spatial identification of locations where public health guidelines are not adhered to can be important for alerting the population about critical points regarding virus transmission, especially given the high mortality and transmission rates present in the pandemic scenario. Thus, this work used gamification to support crowdsourcing and participatory mapping approaches regarding data based on the population's risk perception. Although this study is limited to the use of georeferenced data related to risk perception, the platform contains other non-georeferenced questionnaires related to risk perception. In Figure 5, it is possible to observe the data collection interface for Covid-19 transmission predictors in the platform's mobile environment.

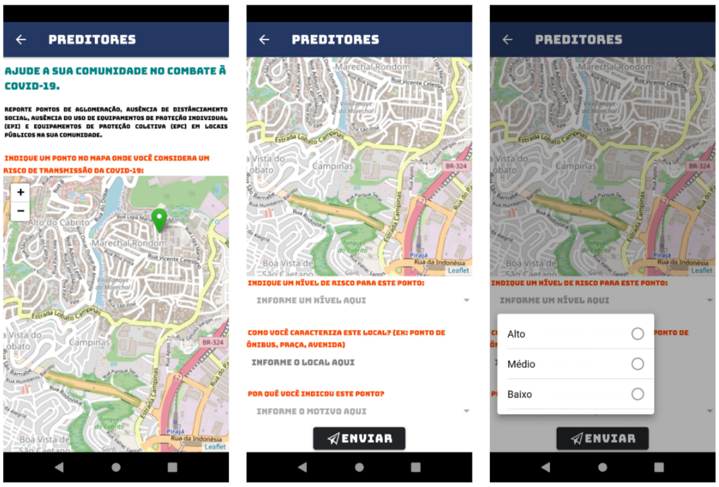

Figure 5. Georeferenced data capture in the mobile application.

Increasingly present in the context of epidemiology, studies utilizing individuals' risk perception are frequently conducted, as they can signal subjective indicators that are often not available in other research approaches. This is because risk perception studies uniquely consider cultural and social factors that can interfere with individuals' perceptions [Giulio et al. 2015].

The proximity alert mechanism operates through communication between the application and the server. Based on georeferenced data stored on the server, the application notifies and spatially signals the user in real-time if they enter a 30-meter radius of an area indicated by the presence of a transmission predictor. In Figure 6, you can observe the interface of this mechanism on the +Lugar platform. It is essential to highlight that this mechanism is addressed by the gamification strategies present in the platform. Thus, the mechanism is related to the narrative created about the context resulting from the Covid-19 pandemic, using avatars. Avatars in this context are referred to as "Defenders".

5. User Study

The study conducted in this work took place within the context of the "Building Healthy Communities in Brazilian Urban Slums" project. The project aims to integrate a community-based participatory approach into an adaptable management framework for designing, implementing, and evaluating interventions. This combines knowledge and action for social change to improve community health and eliminate health disparities. With the participation of 20 young people and adolescents from a suburban community in Salvador, Bahia, in partnership with the collaborative mapping and extension team of the project, virtual meetings were conducted regularly in September and October 2021 through Google Meet. The objective was to present, test, and validate the contributions from this research for the Covid-19 version of the platform.

The instrument used to collect data was an electronic form made available to the research participants. The questionnaire based on the UTAUT was created us-

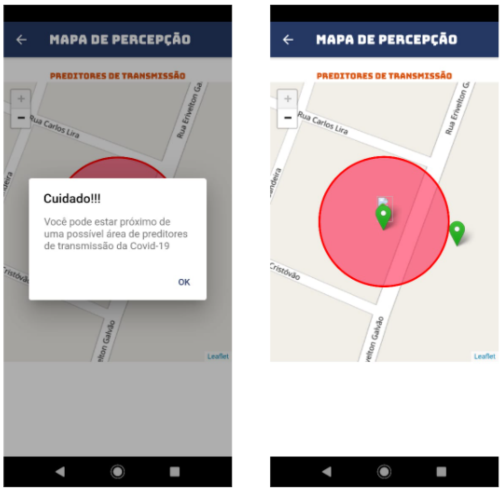

Figure 6. Perception map where all transmission predictors signaled by users are spatialized.

ing Google Forms and included questions about the theory constructs presented in [Venkatesh et al. 2003]. The form consisted of 22 questions, among which there were questions about moderating conditions, determining conditions, and behavioral intention. A Likert scale ranging from "1 = Completely Disagree" to "7 = Completely Agree" was used for the questions related to the determining conditions of the UTAUT. As shown in Table 2, three questions were listed in the questionnaire for each determining condition.

Table 2. Questions about determining conditions.

Questions	
Performance expectation	Q1 - I believe the platform is/will be useful for the Covid-19's confrontation.
	Q2 - Using the platform allowed/will allow me to contribute to the fight against Covid-19.
	Q3 - Using the platform, I have/will have more ways to contribute to facing Covid-19.
Effort expectation	Q1 - My interaction with the platform is/will be clear and easy to understand.
	Q2 - It was/will be easy for me to become a skilled user of the platform.
	Q3 - Learning to use the platform was/will be easy for me.
Social influence	Q1 - People who influence my behavior think I should use the platform.
	Q2 - People who matter to me think I should use the platform.
	Q3 - In general, the Collectives, and Community Associations in my neighborhood have encouraged the use of the platform.
Facilitating conditions	Q1 - I have/will have the necessary resources (hardware, mobile device, internet) to use the platform.
	Q2 - I have/will have the necessary knowledge to use the platform.
	Q3 - A specific person or group will be available to help when I have difficulties with the platform.

5.1. Moderating conditions

Concerning the distribution of participants by gender, 30% of the participants in this study are female, and 70% are male. In terms of the distribution of participants regarding experience in using collaborative platforms (such as Waze, ViconSAGA, Wikipedia, Fogo Cruzado, among others), it is noteworthy that only 15% of the participants indicated having little or no experience with the use of these platforms, while 50% reported having a significant or satisfactory level of experience.

Regarding the distribution of age groups, it is observed that 75% of the respondents were between 15 and 23 years old at the time of filling out the questionnaire. In terms of measures of central tendency, the mode corresponds to the age range of 18-20 years. Concerning the distribution of participants in terms of voluntariness in using the platform, 95% of the participants indicated that they use the platform voluntarily.

5.2. Determining conditions

Participants tend to believe that the presented solution is useful for combating Covid-19, thereby endorsing the value of the provided resources. Furthermore, it is evident that 95% of the participants agree that the platform contributes to the fight against the disease, while 85% believe that using the platform provides them with more opportunities for contribution. Regarding the "Expectation of Effort", participants believe that the presented solution is easy to understand, requires a significantly small learning curve, and they understand that becoming a proficient user of this platform is easy. Consequently, 80% of the participants agree that they are or will become proficient users without significant difficulties, and 75% agree that their interaction with the platform's resources occurs easily and clearly.

Concerning "Social Influence", it is evident that participants can be influenced by others to use the platform. It can be seen that 75% of the participants agree that important people in their social circle believe they should use the platform. Furthermore, 65% of the participants agree that social movements and community collectives have encouraged them to use the platform. Regarding "Facilitating Conditions", participants believe they have the necessary conditions to use the platform. Thus, 80% of the participants agree that they have the required resources to use the platform, and 90% agree that specific support will be available to assist with any potential difficulties related to the platform.

6. Results

Critical aspects of the study findings were investigated, starting with reliability and correlation analysis. We analyze the robustness and consistency of our data and the extent to which variables correlate with each other. Subsequently, the hypotheses formulated in our research are rigorously tested and validated. Through these analyses, we aim to provide a comprehensive understanding of the empirical support for the central claims of our study and the implications of our findings.

6.1. Reliability and Correlation Analysis

To assess the reliability of the questionnaire used in the research, the Cronbach's alpha coefficient was employed, a significant coefficient when it comes to checking the internal consistency of a scale for a set of construct indicators through correlation [Bland and Altman 1997]. The reliability analysis result obtained through the Cronbach's alpha coefficient was 0.86, and the standardized alpha coefficient was also 0.86. Thus, this analysis demonstrates a satisfactory internal consistency. As per Gliem (2003), the Cronbach's alpha coefficient typically ranges from 0 to 1, and any value above 0.70 is generally considered acceptable for the coefficient.

To determine which correlation test to apply to assess a potential correlation between the determinants factors and behavioral intention, the Shapiro-Wilk normality test was used to evaluate the data distribution for each construct, checking for data parametrization. In Table 3, it is possible to observe that the constructs PE, FC, and BI do not exhibit a normal distribution. Since this involves a correlation analysis between pairs of ordinal qualitative variables, the Spearman correlation coefficient was utilized, A coefficient commonly used to perform correlation analysis between pairs of ordinal qualitative variables and which can be used with significantly small sample sizes is the Spearman correlation coefficient [Gauthier 2001].

Table 3. Normality test (Shapiro-Wilk).

Construct	W-Statistic	P	Result
PE	0.865	0.009	Failed
EE	0.919	0.093	Passed
SI	0.940	0.244	Passed
FC	0.858	0.007	Failed
BI	0.893	0.030	Failed

The results of the Spearman correlation test presented in Table 4 demonstrate that the constructs "Effort Expectation" and "Social Influence" exhibit a positive and significant correlation (p-value <0.05) with the Behavioral Intention to use the platform. It is evident that "Performance Expectation" and "Facilitating Conditions" do not show a significant correlation (p-value >0.05) with the Behavioral Intention to use of the platform.

Table 4. Spearman correlation matrix between the determining constructs and Behavioral Intention.

		BI	PE	EE	SI	FC
BI	Spearman correlation	1	0.085	0.468*	0.617*	0.358
	N	20	20	20	20	20
PE	Spearman correlation	0.085	1	-0.091	0.125	0.224
	N	20	20	20	20	20
EE	Spearman correlation	0.468*	-0.091	1	0.499*	0.452*
	N	20	20	20	20	20
SI	Spearman correlation	0.617*	0.125	0.499*	1	0.246
	N	20	20	20	20	20
FC	Spearman correlation	0.358	0.224	0.452*	0.246	1
	N	20	20	20	20	20

* Significant correlation (p-value < 0.05)

6.2. Confirmation of Hypotheses

- **Hypothesis 1: "Performance Expectation" has a positive impact on the Behavioral Intention to use the platform.**
  The results indicate that "Performance Expectation" does not have a significant impact on the intention of platform use by the young and adolescent respondents (p-value >0.05). Therefore, Hypothesis 1 is rejected.
- **Hypothesis 2: "Effort Expectation" has a positive impact on the Behavioral Intention to use the platform.**
  The results indicate that "Effort Expectation" has a positive effect on the Behavioral Intention to use the platform (p-value <0.05). They suggest that young respondents believe it is easy to become a skilled user of the platform, and they judge that the interaction with the platform is clear and easy to understand. Therefore, Hypothesis 2 is confirmed.

- **Hypothesis 3: "Social Influence" has a positive impact on the Behavioral Intention to use the platform.**
  The results indicate that "Social Influence" also has a positive impact on the Behavioral Intention to use the platform (p-value <0.05). They suggest that the respondents' social circle, including people who are important to them, and even community collectives and associations, influence them to use the platform. Thus, Hypothesis 3 is confirmed.
- **Hypothesis 4: "Facilitating Conditions" has a positive impact on the Behavioral Intention to use the platform.**
  The results indicate that "Facilitating Conditions" does not have a significant impact on the Behavioral Intention to use the platform by young and adolescent respondents (p-value >0.05). Therefore, Hypothesis 4 is rejected.

Table 5 shows a summary of the confirmation of hypotheses.

Table 5. Confirmation of hypotheses.

Hypothesis	Correlation result	Confirmation
Hypothesis 1	Not significant (p-value >0,05)	No
Hypothesis 2	Significant (p-value <0,05)	Yes
Hypothesis 3	Significant (p-value <0,05)	Yes
Hypothesis 4	Not significant (p-value >0,05)	No

7. Discussion

Regarding the assessment of acceptance and use of the platform, due to the pandemic context and the lack of sufficient time for effective widespread adoption, this study aimed to understand the factors influencing the intention to use the platform among the young and adolescent participants of the research. Therefore, the construct "Use Behavior" was suppressed from the analysis. Another modification made to the UTAUT application procedure was the omission of correlation analyses for the moderator constructs: Gender, Age, Experience, and Voluntariness of Use. The moderator constructs were presented descriptively to contribute to the participant characterization.

The distribution of participants in terms of their level of experience in using collaborative platforms reflects the use of the +Lugar platform by some young people in the community. This group of young people and adolescents already participate in other projects promoted by the UFBA Collective Health Institute that make use of the +Lugar platform and other collaborative platforms in their activities.

Regarding the assessment of platform acceptance and usage, the descriptive data analysis indicated that the majority of respondents have high levels of performance expectancy, effort expectancy, social influence, facilitating conditions, and behavioral intention to use the platform. However, through the analysis of the Spearman correlation coefficient, it was possible to identify that only the factors of effort expectancy and social influence significantly impact the intention to use the platform. Consequently, performance expectancy and facilitating conditions do not show a positive and significant correlation according to the testing of this coefficient.

Due to the pandemic context experienced during the execution of this research, conducting this study with young people who were already part of the "Building Healthy

Communities in Brazilian Urban Slums" project was essential for the feasibility of this study. The engagement of young people and adolescents in this community in activities with the +Lugar platform had already been observed in the ethical approval process in the early stages of the project.

7.1. Threats to the Validity

One aspect to consider when analyzing the results presented in this study is the non-generalizable nature of this research modality. Participants (N=20) have already been involved in similar applications, which may characterize a lack of randomization in the sample. Besides the action research having a non-generalizable scope, the group of young participants in this study also took part in other research related to the field of epidemiology and other areas within public health, such as ecology and entomology. This involvement could influence their perception of the established determining constructs in the assessment of platform acceptance and use.

8. Conclusion and Future works

The results of this research have indicated that the overall objective, to assess the use of the GAFCC model as a support for participatory mapping and crowdsourcing approaches in practices aimed at combating Covid-19, was notably achieved. Thus, based on the findings presented throughout this study, it is evident that the GAFCC model can be applied in contexts beyond the realm of education. Given the non-generalizable nature of the research methodology used, it is evident that the work conducted can be valuable for conducting new studies that assess the feasibility of implementing the GAFCC model in various healthcare contexts. It can also serve as a basis for the development and adaptation of new gamification design models tailored to this domain.

This study has also demonstrated that the implementation of a gamification design model to support the use of participatory mapping and crowdsourcing approaches in practices aimed at combating Covid-19 in vulnerable communities is a significantly viable procedure. Through the proposed solution, it is expected to obtain spatially distributed indications regarding the presence of Covid-19 transmission predictors in a participatory manner, as well as real-time notification of users' proximity to publicly marked areas under the perceived risk of Covid-19 transmission. Through the proposed approach, it is also expected to obtain georeferenced data at the neighborhood scale, which is made possible by the characteristics of this form of collaboration. In addition to the spatial understanding of transmission predictors being important for the development of prevention strategies and decision-making, in the future, this information can also be associated with other objective disease-related data. It is anticipated that this solution can be explored in other possible epidemiological and public health scenarios.

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