Revista EaD &
tecnologias digitais na educação

Development and validation of InfeQ game as active methodology to learn infectious diseases during medical graduation

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Abstract: *Health education is always in movement, constant changing over the years and adjusting to new challenges, enabling new generations to learn. Through this journey, new methods were created. We recently crossed the biggest Covid-19 pandemic, which accelerated the processes and advances that unite education and technology. Problem-based learning, communication skills training, and simulation-based learning became part of new graduation curriculum. The aim of this study was to introduce a new method of learning in infectious diseases, using gamification. In this project, a mobile application with game components was developed, as an auxiliary teaching tool in infectious and parasitic diseases for medical school students. Residency test questions were selected and presented as: Sexually Transmitted Infections (N=30), General Infectious Diseases (N=101), Antimicrobials (N=33) and HIV/AIDS (N=30). During playing game evaluation, students answer a cycle of 10 objective questions, where correct answers and response speed for classification parameters,*

ranking, are measured. At the end, correct answers to the candidates are reached. Estimates were collected from 116 medical students (N=108) and infectious diseases' specialists (N=8), 35.4% of whom were male with a mean age of 25.8 years. Results showed that the application received a good usability evaluation, obtaining an average SUS score equal to 90.5. The mean CVI was 92.2. The game was registered by the National Institute of Industrial Property, under the title InfeQ®.

Keywords: *Infectious Diseases; Medical Education; Mobile Applications.*

1. Introduction

Higher education consists of teaching and learning process developed in a dynamic context that is influenced by the historical-cultural-economic context. Teaching in the 21st century has undergone several changes in a postmodern and globalized world (Gadotti, 2000).

Educational panorama in Brazil is going through a moment of great transformations, introducing new models that involve autonomy, engagement and new teaching technologies (Gadotti, 2000; Vidal, A.S. & Miguel, J.R., 2020).

Traditional pedagogical models are centered on the teacher and on lectures, forming passive and uncritical professionals, in which there is a deficit in the assimilation of knowledge due to lack of synchronization with clinical practice. As an alternative to this model, active methodologies emerge, centered on the student and as an active subject of the learning process, being stimulated in a critical, resolute, and collaborative path (Shah, R.K. & Campus, S., 2021; Nascimento, J.L. do, & Feitosa, R.A., 2020).

According to the new National Curriculum Guidelines (DCN), medical training includes a critical, reflective, ethical, humanist and transformed scope, in addition to basic theoretical-medical knowledge. In addition, the DCN incorporates digital information and communication technologies (TDIC) in educational activities and in the use of remote databases: a set of media that use digital technology based on a binary language, with devices that allow the use of Internet (Meireles, M.A.C., 2019).

Due to the guidelines of the current DCN, there is a reduction in lectures and a diversification in educational methodologies and technologies, aiming at active, interactive, autonomous and team learning. In this way, TDIC are shown to be a new pedagogical possibility for medical education filled with modern, virtual and dynamic resources (Magalhães, L.V.B. & Li, L.M., 2019; Meireles, M.A.C., 2019).

Advent of digital technology boosted the globalization and modernization of medical education, turning it into a facilitator of learning, allowing integration between technical-scientific knowledge and the means of technology and communication. With this, it allows the development of modern, interactive, and creative teaching methodologies, stimulating the student's interest in the learning process (Meireles, M.A.C., 2019).

Incorporation of TDIC in the teaching process created new teaching modalities, which include distance learning, remote learning, and hybrid learning. In this model, in moments of asynchronous teaching, in which there is no direct interaction between the student and the teacher, the teacher can create several possibilities of activities and teaching mechanisms for the student to use according to their time availability, with gamification being an example (Green, A. & Valero, J.M., 2021; Dichev, C. & Dicheva, D., 2017). In this new model, digital media are responsible for transmitting the knowledge

itself, while the teacher feeds the discussion, stimulates critical thinking, functioning as a study guide. These new technologies have created new spaces for building knowledge, aiming at teaching, and expanding study time by using preferences of current students (Kim, S., 2019).

In December 2019, in Wuhan, China, a disease caused by the new coronavirus – SARS-COV-2 – was discovered. In January 2020 the World Health Organization (WHO) declared a public health emergency and in March 2020 it became a pandemic. In this way, measures of social isolation and restriction on the movement of people were defined, affecting beyond the economic, social and political scenarios, the educational scope, forcing teachers and students to adapt to the new teaching modalities (Mishra, L., 2020).

In the context of pandemic, use of remote teaching was considered a strategy to enable the continuity of the school programs, as well as an attempt to sustain student interest in the learning process, given the rapid and sudden obligation to modify teaching methodologies (Dayagbil, F.T., 2021).

However, there are several challenges in the incorporation of new technologies, difficulties that involve teachers and students as well. Need for training and qualification of teachers for an adequate interaction of teaching components, as well as inequality in the process of globalization and distribution of technologies, with some students still without sufficient means for adequate integration with new technological teaching methodologies – access difficulties, technical limitations to use internet, technological restriction, deepening inequality of access to education (Johnson, A.M., 2016; Darling-Hammond, L., 2020).

Currently, most undergraduate students were born between 1980 and 2000, components of generation called “millennials” or generation Y. As published by the Federal Council of Medicine in May 2021, 58.4% of medical students were between 25 and 29 years old; 30% had between 30 and 34 years; and 11.6% including other age groups (Conselho Federal de Medicina, 2021). Students of this generation need more feedback, more social interaction, use of technology in education, prefer practical, interactive, dynamic activities, games, to opposition of long lectures and reading texts (Haleem, A., 2022).

Unlike the group that preceded them, the X generation, those belonging to Y group are born immersed in globalization and electronic devices. For them, technology means relevance and ability to relate to their peers. On the other hand, generation Y has difficulty concentrating and paying attention, they have unstable behaviors, with impaired reading, which is why objectivity, interactivity and dynamism of teaching should be the focus of students with this generation (Dhanapal, S., 2015; Ogundele, M.O., 2018).

This generation, moreover, grew up watching society experience breaking of paradigms, such as real-time communication in any location, end of dictatorial regimes and expansion of democracy, growth of environmental and sustainability concerns, with absence of major world conflicts. Millennials do not see a medical career as a source of sustainability, but as a lifestyle connected to their values and beliefs, with a desire to contribute to society in their own way (Bollani L., 2019).

The adaptation of generation Y to advanced technologies and the immersion of these technologies in education facilitate learning by meeting the needs of this generation and offering new teaching opportunities, in addition to allowing the sharing of information regardless of geographic location, is a key challenge nowadays.

Therefore, pedagogical methodology based on the use of games, gamification, can promote a better pedagogical result. Although there is a need for further studies in this area, it is known that games have the potential to improve and facilitate the learning process through active interventions experienced by participants. Competition is linked to this process, but the objective is broader, it occurs through the creation of a collaborative, fun, extroverted environment, capable of guaranteeing the learning process while seeking to create a space to reduce anxiety and stress, stimulating natural reward instinct when reaching a certain goal during the game (Camacho-Sánchez, R., 2022; da Silva, R.J.R., 2019). By creating a collaborative environment, gamification promotes knowledge through the exchange of information and experiences among students, in addition to being able to stimulate critical and clinical reasoning.

A game is characterized as any type of competition in which rules are made and created in a specific environment with specific rules, being possible to involve one or several players. Usually, the participants do not focus only on the competition and the confidence of victory, but seek entertainment by creating paths to overcome to reach a certain level or conquest (Dutta, 1999).

According to Marcelo and Pescuite (2009), for creation of a game, we go through some basic steps:

- Game theme: a search is carried out in order to look for something similar to the proposed theme. It's rare to create something totally new, but you should introduce a difference from an already created game theme.
- Mechanics: defined as the programming of actions that the player can perform. Examples: auction, economic development, platform, area domination, etc.
- Duration: How long the game will last, based on the target audience and desired outcomes.
- Gameplay: it is the characteristic that a game has to become simple and intuitive or complex that demands adaptation from the user.

Still according to Marcelo and Pescuite (2009), after creation, the four basic points for structuring a game follow:

- Objectives: every game needs an objective that, when achieved, the player obtains the victory or the opening of a condition that allows to advance in the game.
- Procedures: game script and its set of rules. They are the instructions, what can or cannot be done, conditions for victory.
- Resources: Resources available for players to play their roles.
- Magic Circle: Calling a player's immersion into a new reality represented by game pieces or digital avatars.

Gamification has become a didactic and pedagogical tool, stimulating creativity and providing new ways of building knowledge. It assumes the use of elements traditionally used in games, such as narrative, feedback system, reward system, conflict, cooperation, competition, objectives and clear rules, levels, trials and errors, fun, interactivity, in order to try to obtain the same degree of involvement and motivation in entertainment game players (Pimentel, F.S.C., 2020).

Games are part of the students' daily lives, when creating a game with an educational focus, an important everyday instrument is used as an attraction for interaction and participation in classes.

Digital games with educational purposes are defined as those aimed at academics in which there is room for personal and technical-scientific discovery and growth, in which the curricular content may or may not be displayed explicitly.

2. Objective

The aim of this work was to develop a mobile application as a teaching tool with an active methodology and gamification, with an emphasis on teaching infectious diseases, and its validation among students at a university center in northeastern Brazil.

3. Methodology

Data collection was carried out with students of the fourth semester of the medical graduation at Centro Universitario Christus (UNICHRISTUS), during period from June 07/2022 to June 10/2022. And also applied for infectious diseases specialists at the São José Hospital from March 3/2022 to March 30/2022.

Students participated through use of the application with the infectious disease's questions, which occurred during a previously scheduled date in a lecture, and the application was also available for use at home. Data collection was performed using an electronic form created on the Google Forms platform®, disclosed through the multiplatform instant messaging application WhatsApp®. Data were analyzed with the production of mean SUS score, confidence interval, standard deviation and reliability.

To attest to the reliability of the data obtained, Cronbach's alpha coefficient was used (Bonett and Wright, 2015). The highest possible value for this coefficient is 1.00, with 0.70 considered the lower limit for acceptable internal reliability (Sauro, 2011). The confidence interval for all analyzes was 95%.

System Usability Scale (SUS) is a widely used scale to quantify the usability of various software and hardware products created in 1986 by John Brooke. However, SUS was not created to evaluate mobile or digital health applications (Brooke J.,1996).

The IVC-ES is an instrument to evaluate educational material focusing on three groups: objectives, structure and presentation, and relevance, distributed in a total of 18 questions. This instrument aims to provide a scientific basis to enable the validation of the content of the educational material (Ferreira, D.S., 2020).

The ethical precepts of Resolution 466/2012 of the Brasilian National Health Council were respected, guaranteeing confidentiality, anonymity and non-use of information to the detriment of others.

Data were used only for the foreseen purposes, respecting the dignity and autonomy of the participant. Authorization of participants was obtained through the Term of Free and Informed Consent. Project was approved by the Ethics and Research Committee under CAAE: 52273921.0.0000.5049.

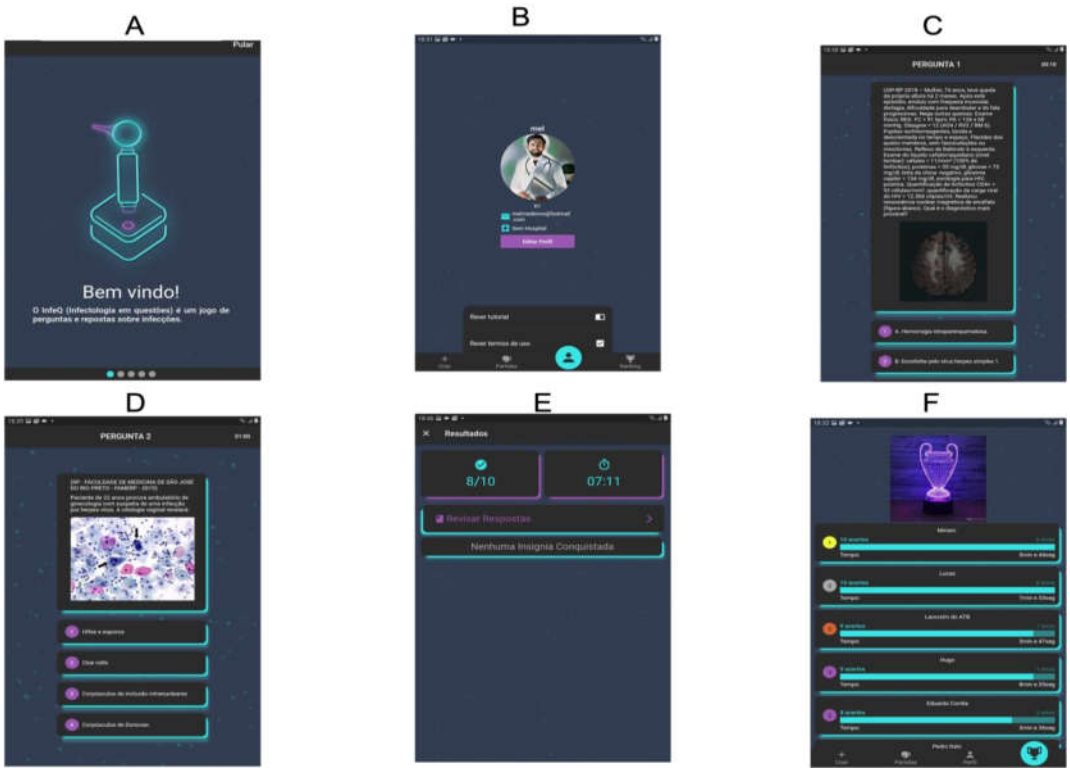
4. Results

There were 116 answers obtained in the evaluation of the mobile application, and 41 (35.4%) of which were male, with a mean age of 25.8 years (var 19-43). There were 108 undergraduate students and eight professionals from the field of infectious diseases responded. Graduation students were attending the fourth semester, in which they were introduced to the topic of Infectious Diseases. When asked if they used mobile games, only 25% (N=29) said yes, the main ones being candy crush (N=2) and patience (N=3). Asked if they accessed educational content applications on their cell phones, 63% answered yes (N=73, the main ones being: 10 related to anatomy, 6 kahoot, 3 academic

books, 10 “Passei Direto”, 23 Sanar and 5 Sanford/Whitebook/Yellowbook) . When asked if they considered gamification as a strategy for academic education, a total of 97.4% (N=113) answered yes.

The game was called InfeQ® and features start screens, profile definition, each player has their time clocked and answers 10 random questions from a total bank of 194, at the end the right and wrong questions are presented, with the possibility of returning to review the wrong question in addition to final ranking (Figure 1).

Figure 1. Screenshots of the InfeQ® mobile application.



Source: author. Images show: A. Welcome to the player on the initial screen, B. Place to build the player profile and register, C. Image of question with laboratory test, D. Example of question with microbiological image, E. Evaluation of correct answers and questions errors, and F. Final player ranking.

Data were analyzed with the production of mean SUS score, confidence interval, standard deviation and reliability. Table 1 demonstrates a summary of the analysis on the questions based on SUS scale to verify the ease of use of the system. Results evidence that application received a good usability evaluation, obtaining an average SUS score equal to 90.5. Studies indicate the value 70.0 as the minimum mean SUS score to consider a system with a good level of usability (Bangor, Kortum & Miller, 2009; Sauro & Lewis, 2012). In addition, it can also be stated, with 95% confidence, that the SUS score for this population is between 88.7 and 92.3 (considering the margin of error equal to 1.8).

Table 1. Analysis of the questions based on the SUS scale to verify the ease of use of the system.

Questions/Likert Rating	**1**	**2**	**3**	**4**	**5**
I think I would like to use this app often (N/%)	0	0	2 (1.7)	36 (31)	78 (67.3)
I find the application unnecessarily complex (N/%)	88 (75.8)	21 (18.1)	6 (5.2)	1 (0.8)	0
I find the app easy to use (N/%)	0	1 (0.8)	2 (1.7)	20 (17.2)	93 (80.2)

I think I would need help from a person with technical knowledge to use the app (N/%)	76 (65.5)	25 (21.5)	8 (6.9)	5 (4.3)	2 (1.7)
I think the app's various functions are very well integrated (N/%)	2 (1.7)	0	9 (7.7)	26 (22.4)	79 (68.1)
I think the application has many inconsistencies (N/%)	77 (66.4)	22 (18.9)	14(12)	2 (1.7)	1 (0.8)
I imagine people will learn how to use this app quickly (N/%)	0	0	3 (2.6)	21 (18.1)	92 (79.3)
I find the app cumbersome to use (N/%)	90 (77.6)	18 (15.5)	7 (6)	0	1 (0.8)
I felt confident using the app (N/%)	1 (0.8)	1 (0.8)	4 (3.4)	23 (19.8)	87 (75)
I needed to learn a lot of new things before I could use the app (N/%)	87 (75)	14 (12)	6 (5.2)	3 (2.6)	6 (5.2)

Source: author. The table shows the questions in the SUS questionnaire.

To attest reliability of the data obtained, Cronbach's alpha coefficient was used (Bonett and Wright, 2015). The highest possible value for this coefficient is 1.00, with 0.70 considered the lower limit for acceptable internal reliability (Sauro, 2011). As can be seen in Table 2, Cronbach's alpha coefficient obtained in this study was 0.79, characterizing the sample with a good level of reliability.

Table 2. Resume of the analysis on the Usability of the application (N = 116).

Variable	**Value**
Sample size	116
Average SUS Score	**90.5**
Confidence Interval	88.7 - 92.3
Margin of error	1.8
Trust level	95%
Standard deviation	9.8
reliability	0.79

Source: author. The table shows the application's usability assessment.

An acceptable content validity index should be at least 0.78 for I-IVC and 0.80 for S-IVC and preferably greater than 0.90 (Yusoff, 2019). If the CVI value is low, it could mean that the items are not good operationalizations of the underlying construct, that the construct's specifications or instructions for the experts were inadequate, or that the experts themselves were biased, erratic, or not sufficiently proficient. This implies that, early in the scale development process, developers must work hard to formulate good items, build clear specifications for the experts, and select a good panel of experts. The CVI-ES index obtained in the study was 92.2, considered acceptable (Table 3).

Table 3. IVC-ES scale for evaluating the construction of the mobile application.

Evaluation	Totally agree (N)	Partially agree (N)	Disagree (N)	IVC (N=116)
OBJECTIVES: purposes, goals or purposes	**2pts**	**1pt**	**0pt**	
1. Contemplates the proposed theme	112	4	0	96.5
2. Suitable for the teaching-learning process	108	8	0	93.1
3. Clarifies doubts about the topic addressed	100	14	2	86.2
4. Provides reflection on the topic	106	9	1	91.4
5. Encourages behavior change	93	22	1	80.2
STRUCTURE/PRESENTATION: organization, structure, strategy, coherence and sufficiency	**2pts**	**1pt**	**0pt**	
6. Appropriate language for the target audience	110	6	0	94.8
7. Appropriate language for educational material	111	5	0	95.7
8. Interactive language, allowing active involvement in the educational process	109	6	1	93.9
9. Correct information	112	3	1	96.5
10. Objective information	111	5	0	95.7
11. Clarifying information	106	10	0	91.4
12. Necessary information	110	6	0	94.8
13. Logical sequence of ideas	106	10	0	91.4
14. Current theme	112	4	0	96.5
15. Appropriate text size	93	20	3	80.2
RELEVANCE: significance, impact, motivation and interest	**2pts**	**1pt**	**0pt**	
16. Stimulates learning	110	6	0	94.8
17. Contributes to knowledge in the area	112	4	0	96.5
18. Arouses interest in the topic	104	11	1	89.6
IVC-ES				**92.2**

Source: author. The table shows the assessment questions about the mobile application components. IVC-ES Calculation = Average of the Sum of Answers 2 (I totally agree)

5. Discussion

The world scenario changes profoundly because of contextual changes resulting from technological and scientific progress. These changes directly interfere with the knowledge acquisition process, as technology is thought of as mediation and as an instrument for transforming the learning process and pedagogical relationships (Peixoto, J., 2012).

Although the study showed a small percentage of students using games on cell phones (25%), the percentage using educational applications was high (63%), which may have been relevant to the good acceptance of InfeQ. Within the educational scope, over the years several changes have occurred due to the evolution of information and

communication technologies and the popularization of the internet, in this way it was possible to insert numerous technologies inside and outside the classroom, such as the use of applications. InfeQ® is an example of a new technological learning format. We know that students of this new generation like to study by solving questions for tests and contests. The playful nature of this mobile application unites the quality of questions already presented in other contests in the country, such as medical residency and public tenders, combined with a game that was very well evaluated in terms of its content and usability.

The use of educational applications as a pedagogical didactic resource, in the new paradigm of education, is a great tool in contributing to quality learning, as they are not just a form of fun, they help and facilitate cognitive development, building through experimentation and of the interaction. In the medical area, studies have shown that the use of mobile and wireless technologies can provide numerous benefits for both professors and medical students, within the concept of Mobile Medical Education (Briz-Ponce, L., 2016).

The worst content evaluations by the CVI scale were: “Encourages behavior change” and “Adequate text size”. We believe that because it is an exclusive game for solving questions, it does not really have the perspective of changing habits, but only adding to knowledge. As for font size, quiz questions are usually large and descriptive, taking up a lot of screen space. Perhaps better choice and re-evaluation options for the question on other screens could have recovered that evaluation.

Gamification comprises an area of study related to playfulness that includes games and activities associated with other themes such as fantasy, imagination, and leisure (Fortuna, T., 2017). This instrument can be understood as a tool for obtaining knowledge in the face of lifestyle changes caused by the rise of new technologies that have modified the learning process (Caillois, R., 2017). In this way, gamification can awaken the feeling of achievement in an engaged and pleasurable way, unlike other forms of evaluating student performance that include traditional processes, specific dates, which can generate stress and anxiety for the evaluated individual, harming, in this way, mental health (Neidenbach, S.F., 2020). In addition, the use of this instrument can induce the student to reflect and reason about their actions, encompassing the autonomous process of decision-making in the face of the knowledge they need to understand (Silva, I. C. S., 2016)

6. Final considerations

Faced with progressive changes in medical education and the need to evolve in the teaching-learning process, the mobile gamification application InfeQ® stands out with the perspective of being used by undergraduate and graduate students who are taking public exams in the field of infectious diseases.

With the appropriate usability and content evaluation, the possibilities of inserting one more active methodology activity in training during medical graduation is evidence of the need to implement new technologies in this scenario.

The limitations of the study point to the need for improvement in the proposals for new versions of games, such as the inclusion of discussion of the question, pointing out the direction for the correct answers, in addition to the evolution towards synchro-

nic competitions among the students, stimulating them from the competitiveness in real time.

From this perspective, we believe that the use of serious games in academic training is not only a methodological innovation, but a real possibility of stimulating to learning.

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