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Personalized Mobile Platform for Improving Health Literacy and Self-Management in Patients with Cardiovascular Diseases

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***Abstract*—Cardiovascular diseases (CVDs) are a group of heart and blood vessel disorders, and they are the leading cause of death worldwide. However, efforts to contain the development of cardiovascular diseases are hindered by the lack of adherence to medical treatments. Despite the beneficial effects of medical procedures and medications demonstrated by science, complications persist in the affected population, and the problem has been associated with the behavior of those who suffer from these pathologies and their level of awareness of the risks they face. The new disruptive paradigms in the healthcare sector include the patient as an active participant in their therapy. Several authors have explored the development of mobile applications aimed at improving health literacy and the treatment of several diseases. Due to the rapid evolution of technology in recent decades, mobile health, which includes smartphone applications, has become increasingly popular in chronic disease management and health promotion. This work focuses on developing a personalized mobile platform to improve health literacy and self-management in patients with cardiovascular diseases. In particular, our platform's design is informed by a health literacy framework that takes into account five key elements: 1) knowledge and social representations of concepts, 2) personalized information, 3) emotional connection to the information, 4) patient-centered behavioral alternatives, and 5) call-to-action instructions. Specifically, the proposed mobile platform includes three interactive modules: Knowledge, My Cardiovascular Risk, and Mental Health. These elements are designed to empower patients with cardiovascular diseases to better understand their condition, make informed decisions about their health, and take action to manage their condition.**

***Index Terms*—Mobile platform, application, health literacy, cardiovascular diseases, patient behavior, mobile health.**

I. Introduction

Cardiovascular diseases (CVDs) are a group of heart and blood vessel disorders [1], and the leading cause of death worldwide. More people die from CVDs than any other cause each year. Additionally, CVDs are one of the major causes of disability and premature death, and their prevention and treatment have become the focus of health professionals [2]. However, efforts to contain the development of cardiovascular diseases are weakened by the lack of adherence to medical treatments. Although cardiovascular drugs have well-established benefits in primary and secondary prevention of CVDs, unfortunately, adherence to these drugs, defined as the extent to which patients take them, is suboptimal.

Although successful interventions to improve adherence do exist, it is estimated that half of the interventions fail, and adherence theories lose their explanatory power. Consequently, a significant number of patients do not obtain the maximum benefit from their medical treatment, which leads to poor health outcomes, low quality of life, and an increase in healthcare costs. In general, adherence rates are higher among patients with acute diseases compared to patients with chronic diseases. Constant adherence among patients with chronic diseases is disappointingly low, and it drops more dramatically after the first six months of treatment [3].

Despite the fact that science has demonstrated the beneficial effects of medical procedures and medications, complications persist in the affected population, and the problem has been associated with the behavior of those who suffer from these pathologies and their level of awareness of the risks they face. People can make decisions that aggravate their condition because they are not aware of their current state or where they could end up based on their behavior.

The new disruptive paradigms in the healthcare sector include the patient as an active participant in their therapy, moving from monitoring systems for data collection to integrated systems [4]. They suggest that monitoring should not only be done to evaluate the state of the therapy, but also for the patient to receive feedback and adjust their behavior with informed readings of their data [5].

In particular, cardiovascular diseases are complex conditions that require a high level of knowledge and skill from the patient in managing their condition. This should include understanding the condition, the ability to manage and manipulate numbers, navigating the healthcare system, communicating with healthcare professionals, and the

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ability to make decisions regarding medical and behavioral strategies [6].

Therefore, new evidence supports the use of health technology to improve patient education and the implementation of skills and behaviors that are an integral part of their treatment [7].

Furthermore, several authors have explored the development of mobile applications aimed at improving health literacy and the treatment of several diseases. Such apps are mainly designed to modify lifestyle habits in diagnosed patients, recollect additional data for outperforming the treatments, and prevent the development of diseases in healthy young people.

For instance, Merino-Godoy et al. (2022) developed a mobile application to educate young people on healthy eating habits, physical activity, and management of interpersonal relationships, as well as to reduce the risk of social media addiction [8]. Walters et al. (2010) developed a care model that efficiently utilizes mobile phones, internet and communication technologies as a means to deliver rehabilitation services to outpatients.

The mobile phones are used for monitoring of exercise and other health data as well as recording patients' self observations on their health related behavior; besides, the patients receive motivational and educational multimedia materials through the phone. This approach has proven to be effective in addressing some of the major obstacles that prevent patients from participating in cardiac rehabilitation programs.

With this approach, there has been a significant increase in uptake, adherence, and completion rates among patients. Furthermore, patients who have undergone rehabilitation through this approach have reported improvements in both their physical and psychological well-being [9]. Bockting et al. (2011) remark that the use of mobile cognitive therapy, i.e. Internet-based intervention including SMS-based monitoring, might be promising in disrupting the rhythm of depression [10].

Xu et al. point out that mobile applications may have a statistically significant improvement on the adherence of cardiac rehabilitation [11]. Additionally, in their systematic review, Debon et al. (2019) identified mobile health applications that have features aimed at improving the lifestyle of patients with chronic diseases, such as diabetes mellitus, arterial hypertension, cardiovascular disease, lung diseases, and cancer [12].

The authors describe the applications they found and how they can improve the treatment of these conditions. Indeed, deepening our understanding of applications for cardiovascular disease, it is worth highlighting the development of the smartphone-based coronary heart disease prevention program, which aims to improve awareness and knowledge of coronary heart disease, reduce perceived stress, and promote positive cardiac-related lifestyle behaviors among individuals with cardiovascular disease [13].

Also related to cardiovascular disease, Smith et al. (2015) have also develop an application to promote healthy habits and basic health information [14], while Pfaeffli Dale et al. (2015) have created an application to educate patients about cardiovascular risk factors and support them in making lifestyle changes [15]. These three applications share common features, such as the ability to record diet habits, physical activity, smoking, and alcohol consumption.

Due to the rapid evolution of technology in recent decades, mobile health, which includes smartphone applications, has become increasingly popular in chronic disease management and health promotion [13]. Mobile health provides a convenient and accessible way for the public to improve their health and overall well-being. Building on this, our work focuses on the development of a personalized mobile platform to improve health literacy and self-management in patients with cardiovascular diseases.

In particular, the design of our platform is informed by a health literacy framework that takes into account five key elements: 1) knowledge and social representations of concepts, 2) personalized information, 3) emotional connection to the information, 4) patient-centered behavioral alternatives, and 5) call to action instructions.

These elements are designed to empower patients with cardiovascular diseases to better understand their condition, make informed decisions about their health, and take action to manage their condition. Specifically, our personalized mobile platform includes a secure and encrypted login system, as well as a main menu that provides access to three modules: Knowledge, My Cardiovascular Risk, and Mental Health. We believe that the development and implementation of this application in healthcare settings has the potential to significantly improve the quality of life for patients with cardiovascular diseases.

II. Materials and Methods

The integration of information and communication technologies (ICTs) in healthcare systems has become increasingly common. ICTs refer to various applications and platforms that allow for the electronic access, storage, transmission, and manipulation of health information [16]. With the current state of mobile phone technology, there is now a highly appealing option for supporting home-based health and chronic disease management programs [9].

The capabilities of mobile communication and technology make it possible to provide users with easy and convenient access to health information and resources, which can greatly improve the effectiveness of healthcare interventions.

Particularly, smartphones have become an indispensable technology platform for personal health management, thanks to their computing power, user interface, memory, and communication capabilities. They are considered personal and trusted devices that people carry with them at all times, even during exercise and daily tasks. Smartphones also enable users to conduct daily errands and financial transactions on the go. In addition to their convenience, smartphones offer a unique opportunity for health service providers to deliver multimedia

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communication and information to patients at a personal level, with the potential for real-time feedback.

Given their high penetration rate in most countries, smartphones are an attractive tool for improving health-related behavioral choices and promoting better health outcomes.

To take advantage of this technological access, it is necessary to build a route in a structured way through health literacy, which allows the user to develop knowledge about the disease and better understand their situation in order to reach the right decision-making. All this is normally achieved through the exchange of information with health professionals and, in this case as support, through interaction with information technologies.

For the World Health Organization (WHO), health literacy is defined as the social and cognitive skills that determine the level of motivation and the ability of a person to access, understand and use information in a way that allows them to promote and maintain good health [17]; for the American Medical Association, it is the constellation of skills, including the ability to perform basic reading and numerical tasks necessary to function in the healthcare setting [18]. Based on these definitions, multiple models have been proposed that describe the construction of knowledge through numerical skills and communication skills that will allow us to understand the usefulness of the information and reach the best possible decision-making.

Within the most prominent health literacy models, there is Dunn and Conard's, which include knowledge of where and when to look for information, verbal communication skills, assertiveness, application skills and the ability to process and have information [19].

Geboers et al. (2018) propose a more comprehensive approach to health literacy interventions, integrating and highlighting the social context as a participant, together with the patient's personal characteristics, communication between the individual and health personnel, the personnel's skills in health and the health system [20].

In other models, such as Edwards and collaborators, in 2018, the role of health professionals is also proposed as a determinant for health literacy, as they act as facilitators (through support, explanations) or as limitations (through the creation of barriers). An environment where an exchange of information between health personnel and the patient is stimulated and facilitated, in search of information that guides the patient's behavior and personal decision making, can lead to better health literacy results [21].

In the ways of addressing health literacy, it is found that models are based on structures similar to traditional academic literacy, and that it is necessary to involve other factors that make parts of the ways of interpreting cardiovascular diseases, such as emotional regulation of the patient and the learning derived from the social experiences that allow decisions.

Based on the above, our work focuses on the development of a personalized mobile platform to improve health literacy and self-management in patients with cardiovascular diseases. In particular, the design of our platform is informed by a health literacy framework that takes into account five key methodological elements:

- **Knowledge and social representations of concepts:** this component offers patients accurate and relevant information about cardiovascular pathologies, symptomatology, and anatomy. The explanations are presented in clear and understandable language to ensure patients can comprehend the information.
- **Personalized information:** This component tailors the information provided to each patient based on their demographic characteristics and health status.
- **Emotional connection to the information:** This component is for creating an emotional connection between the patient and the information provided, which can help motivate patients to take action to manage their condition.
- **Patient-centered behavioral alternatives:** This component aims to empower patients to make informed choices about their health, including options for healthy lifestyle changes.
- **Call to action instructions:** This component aims to motivate patients to take active steps towards managing their condition, which may include adhering to their medication regimen, achieving their health goals, adopting healthy lifestyle changes, or seeking medical assistance when needed.

In this sense, our personalized mobile platform includes a secure and encrypted login system, as well as a main menu that provides access to three modules (see Figure 1): *Knowledge*, *My Cardiovascular Risk*, and *Mental Health*. In this regard, the module called *Knowledge* prioritizes the definitions that the patient should be aware of based on certain clinical and sociodemographic variables. *My Cardiovascular Risk* module provides patients with their individual risk results based on their database records. Finally, the *Mental Health* module presents a set of educational videos for improving the mental health status of patients with cardiovascular diseases.

Taking into account the purpose and scope of the proposed mobile platform, the development model used for the smartphone application was the evolutionary development model. This model involves the integration of specification, development, and validation activities. The process begins with the creation of an initial system based on general specifications, which is then improved based on client requests to meet their specific needs. In this case, the client was the research team, who established the needs based on the state of the art, facts, and requirements of the clinical professionals.

This approach employs exploratory evolutionary development with prototype modeling, where the aim is to collaborate with the customer to identify their requirements and provide a final system that gradually evolves by adding new features. The process starts with the parts of the platform that are well-understood and progressively integrates new functionalities based on customer feedback.

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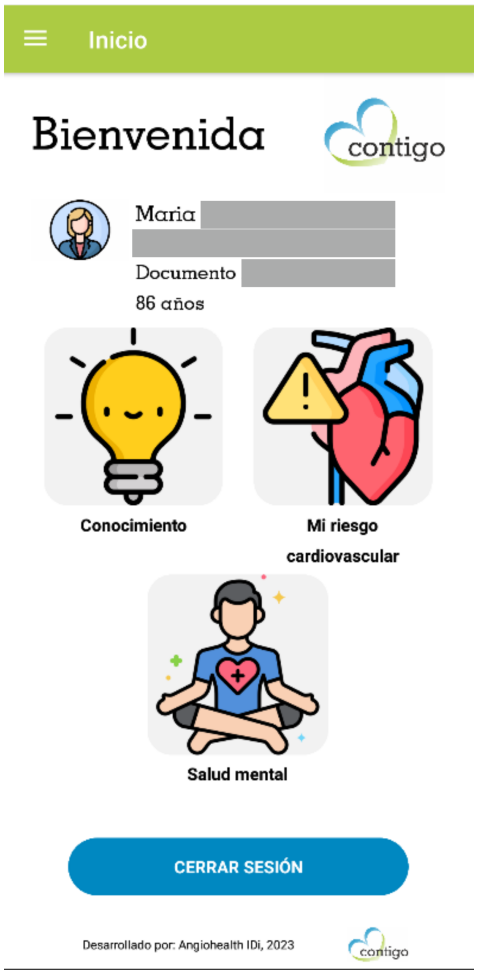

Fig. 1. Application main menu. An app for improving health literacy and self-management in patients with cardiovascular diseases

Therefore, the initial implementation undergoes modifications and adjustments through different versions until the system meets all requirements.

Going forward in the development process, in this project it was necessary to use two design patterns in order to achieve specific goals; expressly, the Model-View-Controller (MVC) and the Model-View-ViewModel (MVVM) patterns are considered. The former, MVC, separates an application's data, user interface, and control logic into three interconnected components: a) the Model that represents the application's data and business logic.

It is responsible for managing data storage, processing data, and handling data-related tasks; b) the View that represents the user interface of the application. It is responsible for displaying data to the user in a visually appealing and interactive way, and c) the Controller, who acts as an intermediary between the Model and the View. It receives user input from the View, updates the Model accordingly, and updates the View to reflect any changes made to the Model.

The main idea behind MVC is to separate the concerns of an application into separate modules, each with its own responsibilities. This makes it easier to maintain and modify the application over time, as changes can be made to one component without affecting the others. Additionally, MVC provides a clear separation of concerns, making it easier to understand and test each component individually [22], [23].

The latter, MVVM, is similar to the MVC pattern, but with some key differences. In the MVVM pattern, the view and the model are still separate components, but instead of a controller, there is a *view model* that mediates between the two. The *view model* exposes the data and functionality of the model to the view, and it also provides data binding between the two. The *view model* is responsible for managing the state and behavior of the view, and it communicates with the model through data binding and other mechanisms. The *view model* is also responsible for handling user input and interaction, and it can trigger updates to the view and the model as needed [14].

According to the requirements of this project, the MVC pattern is used to collect and store encrypted information from a centralized No-SQL database that contains demographic and clinical data of patients. This involves the use of the Model and Controller components of the MVC pattern. Meanwhile, MVVM is used to separate the user interface from the business logic and Model, creating clean and organized code that makes it possible to access any of the mobile application views, facilitating data presentation and collection.

Additionally, the *view model* component acquires or sends data stored in the database through data binding to the View. The connection between the application and the No-SQL database is made through REST-JSONAPI type calls, with communication taking place via the exchange of JSON data. In the model, the *Python Flask* microframework is used as the main server to build an API that uses *Werkzeug* to manage routing and communication between the mobile application and the database (see Figure 2).

III. Results

The main result of this work is the design and implementation of a personalized mobile platform to improve health literacy and self-management in patients with cardiovascular diseases. As previously mentioned, our platform's design is based on a health literacy framework that incorporates: knowledge and social representations of concepts, the use of personalized information, emotional connection to the information, patient-centered behavioral alternatives, and call to action instructions.

The mobile application features a secure and encrypted login system, along with a user-friendly main menu that grants access to three interactive modules, and a secondary menu that displays information about the application's purpose, terms and conditions, version number, and contact information. The application was implemented for use by the patients or their caregivers enrolled in the cardiovascular risk program of the clinical institution that developed the application.

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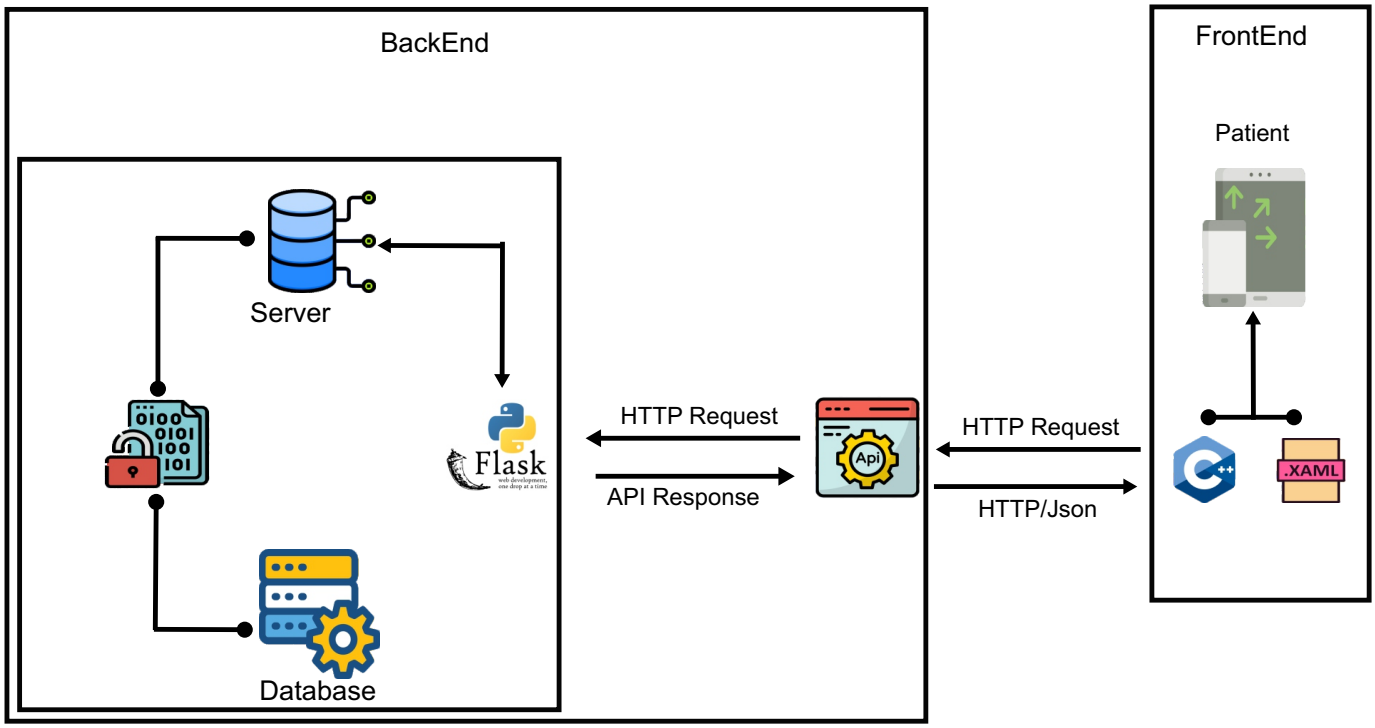

Fig. 2. Hybrid design approach: Utilizing MVC and MVVM patterns for application development

As mentioned above, the first module of the main menu is called *Knowledge*, which features 61 physiological and pathological definitions presented in everyday language (see Figure 3a). These definitions are prioritized for the user based on their clinical picture and demographic condition.

The language clarity of the entire application was a priority during its design, but it is particularly important in this module because many patients may lack medical knowledge and struggle with medical terminology. By using everyday language to explain physiological and pathological conditions, the application can facilitate a better understanding of what is happening in the patient's body.

This increased understanding can empower patients to participate more fully in their treatment plans and make informed decisions about their healthcare. Additionally, presenting information in everyday language can help to reduce the stigma associated with certain conditions, decreasing fear and misunderstanding, which in turn can encourage individuals to seek help and treatment.

The application automatically characterizes patients based on their primary and secondary diagnoses, presence of physical disabilities, body mass index category, cardiovascular risk category, age group, sex group, and medication used by means of 37 tags. Similarly, a group of clinical experts in medicine, nursing, and psychology labeled each definition with the same 37 tags. These tags establish a relationship between patients and definitions, allowing the application to prioritize the most relevant information for each patient. While patients can view the entire set of definitions, the most relevant ones for each patient are highlighted.

The second module on the main menu is called *My Cardiovascular Risk*. This module uses clinical and demographic variables to estimate the probability of a 10-year risk of myocardial infarction, stroke, or cardiovascular death, according to tables published by the World Health Organization in 2019 (Kaptoge, 2019).

The module presents the user's cardiovascular risk probability in a personalized way and provides information on how to interpret the value. Additionally, it offers specific recommendations for risk reduction based on the user's medical records and encourages patients to modify their lifestyle habits to lower their risk. By tailoring the recommendations to the patient's individual health profile, this module can improve their understanding of their condition, increase their engagement in their own care, and lead to better health outcomes (see Figure 3b)

Finally, the third module on the main menu is called *Mental Health*, which offers an educational video course designed to improve mental health status, particularly in patients with cardiovascular diseases (see Figure 3c). The module aims to promote the importance of self-care and identify the main protective factors that can strengthen patients' well-being, as well as the risk factors that increase the probability of developing a mental illness. Another important goal of the module is to encourage the use of coping and emotional regulation strategies, which can help patients better manage their chronic diseases.

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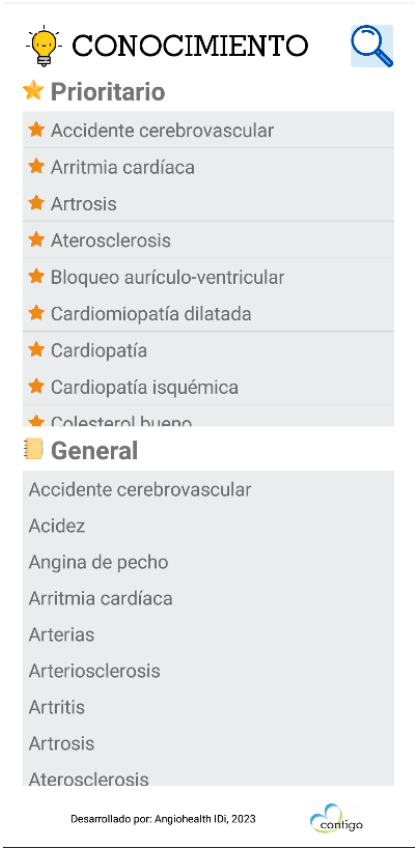
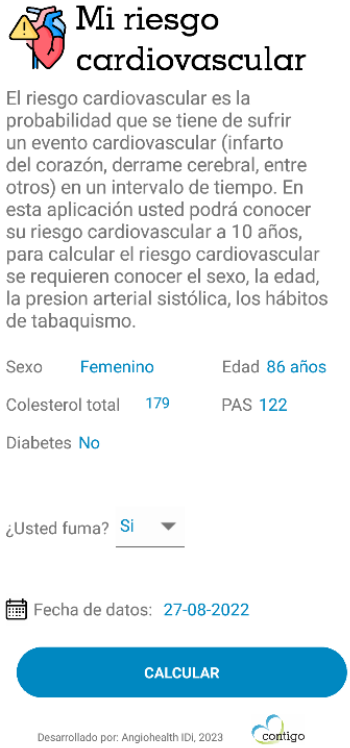


(a) Screenshot of the *Knowledge* module



(b) Screenshot of the *My Cardiovascular Risk* module

(c) Screenshot of the *Mental Health* module

Fig. 3. Three main modules of the application: *Knowledge*, *My Cardiovascular Risk*, and *Mental Health*

Through the video course, patients are motivated to adhere to their clinical treatments in order to improve their overall quality of life. By promoting self-care and emotional regulation strategies, the module seeks to improve patients' resilience and ability to cope with the emotional impact of their condition. In addition, the module emphasizes the importance of seeking professional help when needed and provides patients with practical tools and strategies to support their mental health. Overall, the Mental Health module serves as a valuable resource to help patients better understand and manage the emotional and mental challenges associated with their cardiovascular disease.

IV. Discussion and Conclusion

It is important to highlight that among patients with chronic diseases, the level of literacy also directly impacts the quality of life related to health [24]. It has been found that, during a medical consultation, patients can only understand 50% of what is discussed [25], a place where information technology can complement this entire literacy process and strengthen the factors that may lead to a better adherence.

In this sense, the personalized mobile platform developed in this work is designed to improve health literacy and self-management in patients with cardiovascular diseases. The application developed is based on a comprehensive model of health literacy, distinguished by the approach to social representations and emotional literacy, in order to achieve an individualized approach that allows for better results in decision-making around their diseases.

Through the design of the application, the exchange of clear and constant information is prioritized and facilitated, seeking optimal feedback to the patient as a source of knowledge that leads to better decision-making around their disease. The platform's design is based on a health literacy framework that takes into account five key methodological elements, including knowledge and social representations of concepts, personalized information, emotional connection to the information, patient-centered behavioral alternatives, and call to action instructions.

The application's three interactive modules, Knowledge, My Cardiovascular Risk, and Mental Health, are specifically designed to meet the needs of patients with cardiovascular disease. By providing accurate and relevant information about cardiovascular pathologies, symptomatology, and anatomy in everyday language, the Knowledge module can improve patients' understanding of their condition and empower them

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to participate more fully in their treatment plans. The My Cardiovascular Risk module provides patients with a personalized estimate of their cardiovascular risk and specific recommendations for risk reduction based on their individual health profile. Finally, the Mental Health module offers an educational video course that promotes the importance of self-care, identifies protective and risk factors for mental health, and provides patients with practical tools and strategies to support their mental health. Overall, the personalized mobile platform has the potential to improve health outcomes and quality of life for patients with cardiovascular disease by providing them with personalized information, emotional support, and practical tools to manage their condition.

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