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Prototype of a mobile application for monitoring childhood immunizations

Prototipo de aplicación móvil para el seguimiento de vacunación infantil

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Abstract

The objective of this research is to develop a mobile application in order to notify parents about the dates established for childhood vaccination, as well as to inform about the biological to be applied. The methodology used is Extreme Programming (EP); It consists of 4 phases: Planning, design, coding and testing. This prototype allows the interaction of a user, due to the fact that an informative scope was initially defined; but interaction with doctors and nurses is foreseen thanks to the proposal that is proposed to be made with the Sanitary Jurisdiction No. 10 of Huejutla de Reyes, Hidalgo in the Huasteca Hidalguense. It is intended to reduce different causes that affect the health of the child population, and that is that most parents do not vaccinate their children according to the schedule recommended by health institutions due to different circumstances. As a result, infants do not receive the vaccine when appropriate; Therefore, the risks they could take are dangerous to their health, affecting their future growth. This tool will prevent the loss of information derived from the loss of the vaccination card, as well as the duplication of the information regarding the applications made.

Prototype, Web, Vaccination

Resumen

El objetivo de esta investigación es desarrollar una aplicación móvil con la finalidad de notificar a los padres de familia sobre las fechas establecidas para la vacunación infantil, así como informar sobre el biológico a aplicar. La metodología utilizada es Programación Extrema (PE); consta de 4 fases: Planeación, diseño, codificación y pruebas. Este prototipo permite la interacción de un usuario, debido a que inicialmente se definió un alcance informativo; pero se prevé la interacción con doctores y enfermeras gracias a la propuesta que se plantea hacer con la Jurisdicción Sanitaria No. 10 de Huejutla de Reyes, Hidalgo en la Huasteca Hidalguense. Se pretende disminuir diferentes causas que afectan a la salud de la población infantil, y es que la mayoría de los padres no vacunan a sus hijos de acuerdo con el calendario recomendado por las instituciones de salud por diferentes circunstancias. En consecuencia, los infantes no reciben la aplicación de la vacuna cuando corresponde; por lo tanto, los riesgos que podrían contraer son peligrosos para la salud, afectando su crecimiento a futuro. Esta herramienta evitará la pérdida de información derivada del extravío de la cartilla de vacunación, así como la duplicidad de la información referente a las aplicaciones realizadas.

Prototipo, Web, Vacunación

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Introduction

Immunisation is the process by which a person becomes resistant to a disease, either through contact with certain diseases, or through the administration of a vaccine. Vaccines stimulate the body's immune system to protect a person against infection or disease.

Immunisation is important because it prevents vaccine-preventable diseases, disabilities and deaths, such as cervical cancer, polio, measles, rubella, mumps, diphtheria, tetanus, pertussis, hepatitis A and B, bacterial pneumonias, rotavirus diarrhoeal diseases and bacterial meningitis (PAHO, 2023). (PAHO, 2023).

The research "Prototype of a mobile application for the follow-up of childhood vaccination" involves in its first stage the development of a tool that speeds up and promotes the application of vaccines in infants in the Huasteca Hidalguense region, so its use so far is informative; in later stages, the management of the history record will be implemented to ensure the integrity of the information of each immunisation application by medical personnel, with the use of norms and standards corresponding to the processing of medical information.

The prototype was created to operate in a mobile environment, due to the advantages involved in the use of this type of device today.

The use of the technological tools, React Native, Visual Studio Code and Mongo DB was necessary for the development of a digital child vaccination booklet that notifies parents of the information corresponding to the vaccines that are available for application to infants.

Since misinformation is one of the main causes that prevent health units in the Health Jurisdiction No. 10 of Huejutla de Reyes, Hidalgo from satisfactorily complying with child immunisation campaigns, the initial objective of this research is to communicate to the population the personalised calendar of application of the different biologicals; with the intention of including functionalities in a later phase that complement the interaction with more users such as doctors and nurses to manage medical records in an appropriate, controlled and secure manner.

This article includes the following sections: Problem that indicates the circumstances that originated the development of this research work, the following section corresponds to the justification where the possible solutions, benefits and impact that this project will bring as a consequence are indicated, continuing with the objective to be achieved.

The theoretical foundations that include the necessary information that gives notion and facilitates the perception of the reader for the understanding of the subject treated, the methodology indicates the stages that must be developed to carry out the creation of the prototype; then, the development specifies each one of the activities carried out within these phases.

It also includes the results obtained compared to the project approach with the established objective, the conclusions obtained from this research, as well as the acknowledgements and references used.

Problem

The Universal Vaccination Programme (PVU) in Mexico is a benefit aimed at the general population, whose objective is to protect against diseases that are preventable through the application of vaccines.

Unfortunately, for parents living in the Huasteca Hidalguense region, information on child vaccination campaigns is only available through the traditional means used by the Ministry of Health, most of them printed, which are insufficient and difficult or impossible to access due to the fact that health units are often far from the indigenous communities of the region.

Although nowadays it is increasingly common for people to acquire some type of mobile device with which they can access an internet connection point, in this demarcation there is no tool through these terminals that notifies and keeps the population informed about current immunisation campaigns for children, which leads to incomplete and deficient coverage.

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In addition, the loss, renewal or duplication of child immunisation cards are other causes that particularly occur, and the need to go to a health centre to request a new one or to update the history to determine which biologics have already been applied and which have not, requires time to verify the previous records that the health unit has, resulting in a conflictive situation to resolve for both medical staff and parents.

Justification

Information and Communication Technologies (ICTs) have been surprisingly fast-moving. The resources, tools and programmes available for learning, sharing and disseminating knowledge through different technological supports, applied to clinical practice with the aim of improving the care of children, adolescents and their families surround and amaze us.

The technology that we see most widely used and applied in paediatric practice is mobile devices and their applications. The term "mobile health" refers to the use of these devices for the practice of medicine and public health. Mobile Health is the use of mobile devices (mobile phones, tablets, iPods, etc.) in the health sector, regardless of whether we are a patient, medical professional, institution, government or company (Sociedad Chilena de Pediatría, 2019).

The development of this mobile application has the solution of specifically scheduling vaccination dates and notifying the population in advance about the application of the vaccine to infants, in order to facilitate the important responsibility of protecting the health of all children.

Its benefits have an important impact because, in the first instance, a large part of the population will be able to receive notifications about the vaccination schedule from their mobile device; and subsequently they will be able to count on a tool that will allow quick and secure access to the information corresponding to the vaccination history by parents and medical personnel, avoiding loss or duplication of records.

Objective

To develop the prototype of a mobile application, through the use of the technological tools, React Native, Visual Studio Code, React Navigation, Mongo DB, for the creation of a digital child vaccination booklet that notifies parents of the information corresponding to the vaccines that are available for application to infants.

Theoretical foundations

Immunisation

Immunisation is a simple and effective way to protect children and reduce the spread of serious infectious diseases in this group. Comprehensive immunisation programmes are a cornerstone of prevention and stand out as one of the most cost-effective public health interventions (Hernandez, Palacio, Hernandez, Charvel, 2020). Vaccines differ from medicines in their biological nature, as they are designed to prevent disease and are generally administered to healthy people; thus, their manufacture, distribution, control and regulation require special knowledge and procedures.

They are distributed and marketed through programmes with well-organised health structures, and require post-vaccination surveillance to provide information on events not recorded in clinical trials (Tuells, 2016).

Universal Vaccination Programme in Mexico

The Universal Vaccination Programme (PVU) is one of the Federal Government's main tasks in preventing, eradicating and eliminating diseases from Mexican territory.

The purpose of the Universal Vaccination Programme (PVU) is to reduce morbidity and mortality from vaccine-preventable diseases, to achieve and maintain vaccination coverage of 95 per cent for each biologic and 90 per cent coverage with a complete schedule in each age group (Government of Mexico, 2019). But over the past 12 years, the number of vaccines included in the basic schedule tripled, resulting in increased pressure on primary health care systems to ensure a continuous and adequate supply of vaccines for the 2.2 million children born each year in our country. (Vaccine Alliance, 2023).

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Vaccination in the state of Hidalgo, Mexico

The National Centre for Child and Adolescent Health (CeNSIA) presented the sectoral coverage of vaccination schedules for the year 2022 for children under 1 year (figure 1), 1 year (figure 2), 18 months (figure 3), 4 years (figure 4) and 6 years (figure 5). The information corresponds to the registry of doses applied for Hidalgo and on a sectoral basis (Government of Mexico, 2023).

For children under one year of age, the figures are as follows:

Figure 1 Sectoral vaccination coverage in children under 1 year of age in Hidalgo, 2022
Source: Government of Mexico

Vaccination results obtained for one year olds:

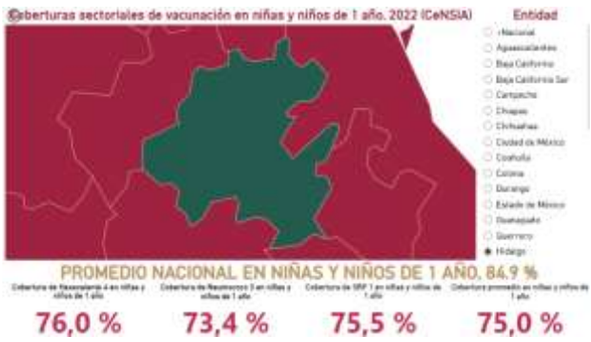

Figure 2 Sectoral immunisation coverage of 1-year-old children in Hidalgo, 2022
Source: Government of Mexico

Immunization coverage for 18-month-old children:

Figure 3 Sectoral vaccination coverage of children aged 18 months in Hidalgo, 2022
Source: Government of Mexico

State and national average vaccination coverage of 4-year-olds:

Figure 4 National and state (Hidalgo) averages for childhood immunisation up to 4 years, 2022
Source: Government of Mexico

State and national average of vaccination of children aged 6 years old:

Figure 5 National and state (Hidalgo) average of childhood immunisation up to 6 years, 2022
Source: Government of Mexico

Statistics show that child immunisation coverage percentages in the state of Hidalgo, in most scenarios, are below the national average, with the exception of the sector composed of infants aged 4 and 6 years.

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Although in this state the percentage of immunisation for the 18-month-old sector is higher than the national average, it is important to highlight that only 47.8 per cent of children of that age have received the vaccines they are entitled to, which is a very worrying figure.

For the other sectors, although vaccination coverage is higher than the national average, it is also desirable that the percentages can reach the levels proposed by the federal government through the Universal Vaccination Programme (PVU); for this it is necessary to have the support of mobile devices to facilitate and increase the reach in the dissemination of information regarding vaccination campaigns for the largest possible number of the population.

Mobile health

Mobile health (mHealth) is one of the most sought-after terms in the area of health sciences today; however, its definition as an interdisciplinary technological tool could be confused between the concepts of electronic health (eHealth), which is where it originates, or ubiquitous health (uHealth), which uses more complex technological elements to achieve monitoring through sensors and devices (Rodríguez, Gogeascoechea, 2022).

ICTs represent the set of resources based on digital equipment that actively process information. Some of their objectives are: to assist in education; to enable the exchange of information; to solve health problems; to improve referrals and counter-referrals at different levels of care; to prevent and promote health; and to serve as strategic allies of public health (Pan American Health Organization, 2016).

In the last decade, mobile health, the branch of eHealth broadly defined as "the use of mobile communication and computing technologies in healthcare and public health", has been steadily expanding. Mobile health applications can target heterogeneous audiences such as doctors, nurses, patients or even healthy individuals (Free, Phillips, Felix, Galli, Patel, Edwards, 2010).

The biggest advantage of using mobile devices, and in particular mobile phones, for health is that they are personal, smart, connected and always with people (Whittaker, 2012 and Fogg, Adler, 2009).

In addition, Short Message Service (SMS) text message reminders have been shown to be a simple and efficient option for health services to use to improve service delivery, resulting in health benefits for the patients who receive them (Guy, Hocking, Wand, Stott, Ali, Kaldor, 2012). Nowadays, various instant messaging applications are also available for user notifications.

In this regard, information and communication technologies (ICTs) can play an important role in providing easier and more affordable access to health and treatment services.

With people's increased interest in this communication tool, an opportunity has been created for health experts to educate people and increase the health of society. In addition, smartphone services can overcome the limitations of time and place and make healthcare more accessible, especially for people living in remote areas. This technology also provides a suitable ground for the fair delivery of health services to all along the entire care chain (Zare, Hajizadeh, Mahmoodi, Nazari, Shahmoradi, Rezayi, 2023).

In Mexico, the outlook is encouraging in terms of the number of people with smartphones. The estimated number of users for 2026 (Figure 6) is 118.1 million inhabitants (Statista, 2023), suggesting that these devices will be a key tool for the development of health-focused applications.

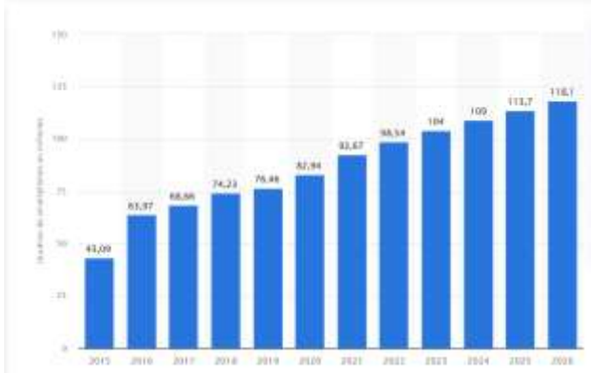

Figure 6 Number of smartphone users in Mexico from 2015 to 2026
Source: Statista (2023)

Methodology

The Extreme Programming (EP) methodology was chosen for the development of this research. It encompasses a set of rules and practices that occur in the context of four framework activities: planning, design, coding and testing.

The decision to choose EP is because this research required little time for its realisation and an important characteristic of the work is that the development is done in pairs.

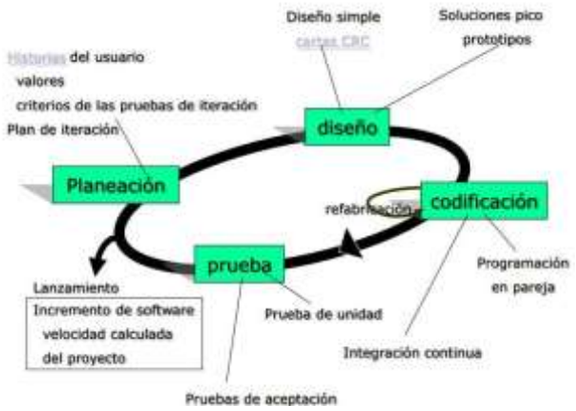

Figure 7 Extreme Programming (EP) process

The planning activity begins by creating a series of stories (also called user stories) that describe the features and functionality required for the software to be built. They are assigned a cost, which is measured in development weeks.

Once the first release of the project (also called software increment) has been delivered, the EP team calculates the project velocity. Put more simply, project velocity is the number of customer stories implemented during the first release.

The SP design rigorously follows the MS (Keep It Simple) principle. A simple design is always preferred over a more complex presentation. In addition, the design provides an implementation guide for a story as written.

For coding, the EP recommends that after designing the stories and doing the preliminary design work the team should not move to coding, but should develop a series of unit tests that exercise each of the stories to be included in the actual release (software increment).

Once the unit test is created, the developer is better able to focus on what needs to be implemented. When the code is complete, the unit can be tested immediately, thus providing instant feedback to the developers.

PE acceptance testing, also called customer testing, focuses on the overall features and functionality of the system, elements that are visible and reviewable by the customer. Acceptance tests are derived from user stories that have been implemented as part of a software release (Pressman, 2006).

Development

In the first phase, the project requirements and the activities to be carried out during the development of the project were identified, as well as the time allocated for each user story.

The user stories developed for the prototype of the mobile application for monitoring child immunisation were defined for the users who would initially use this tool: Administrator (table 1) and Parent (table 2).

An example story for each user is shown below:

Administrator	
Number: 1	User: Administrator
Name Story: Insert data	
Priority in the system: High	Development risk: High
Estimated points: 7	Assigned Iteration: 1
Programmer in charge: Adrián Bautista Cortes and Adrián Hernández Bautista.	
Description: The administrator requests to be able to insert new data into the system.	
Validation: The administrator will be able to insert new data.	
Iteration: User history of the administrator to insert data. Elaboration time: 30 May to 03 June 2023.	

Table 1 User History Administrator

User	
Number: 5	User father
Name History: Infant Data Record.	
Priority in the system: High	Development risk: High
Estimated points:	Assigned Iteration: 1
Programmer in charge: Adrián Bautista Cortes and Adrián Hernández Bautista.	
Description: The user requests to be able to register infant data.	
Validation: The user will be able to register data.	
Iteration: Parent's user story to register the infant's data. Processing time: 27 to 29 June 2023.	

Table 2 User Story Parent

Subsequently, the Planning Poker was used. The purpose of this process is to calculate the effort required to carry out the different user stories, by means of a consensus between the members in charge of carrying out the different tasks that make up each phase.

The technique consists of each team member choosing an option from the Modified Fibonacci, which represents the estimated value of the effort he/she considers for the task without showing it to his/her teammate so as not to influence his/her decision.

The values of the Modified Fibonacci are: 1, 2, 3, 5, 8, 13, 20, 40, 100. In the Planning Poker (table 3) the values of each team member and the average estimate of each user story are observed, as well as the priority of each one of them.

User History	Member		Average estimate	Priority
	A	B		
HU01	40	100	70	High
HU02	20	13	16.5	Medium
HU03	13	8	10.5	High
HU04	20	5	12.5	Medium
HU05	40	20	30	High
HU06	20	13	16.5	Medium
HU07	20	5	12.5	High

Table 3 Planning Poker

Once the estimate in hours was defined, sprints were organised based on user stories to develop the different functions.

As shown in table 4, 7 weeks were used to develop the mobile application, which included 35 working days, which in turn established 7 hours of work per day; therefore, the total number of hours for the sprint was 245.

Sprint size	7 weeks (35 working days)
Work per day	7 hours.
Sprint hours	245 hours.

Table 4 Sprint of the user stories

It can be seen in table 3 that several stories have different priorities, so when this situation arises, it is up to the team to select those with high importance.

The sprint planning considers the maximum number of hours established, in this case 35. If the work required to finish a user story exceeds this time, more iterations will be carried out until the responsibility is completed.

For user story HU01, 70 hours were needed, so two iterations were enough to complete the estimated time. It is worth mentioning that in the first sprint, the first 35 hours were worked, while in the second sprint, the 70 hours were completed to finish the activities of HU01. Tables 5 and 6 show the information corresponding to the time spent for HU01.

Maximum hours per sprint:	35
Total hours used:	70
Remaining hours per sprint:	0
History: HU01	Estimated hours: 70
Iteration:	1

Table 5 First iteration for user story (HU01)

Maximum hours per sprint:	35
Total hours used:	70
Remaining hours per sprint:	0
History: HU01	Estimated hours: 70
Iteration:	2

Table 6 Second iteration for user story (HU01)

In user story HU05 (table 7), the estimated hours for its completion were 30; because the iteration consists of 35, there was a resulting gap of 5 hours that were used for the development of other functions of the mobile application.

Maximum hours per sprint:	35
Total hours used:	30
Remaining hours per sprint:	5
History: HU01	Estimated hours:: 30
Iteration:	1

Table 7 First iteration for user story (HU05)

This procedure was applied for each of the user stories established in the development of this project.

Figure 8 shows the work carried out in the design stage, where the sketches were created for the development of the tool corresponding to the mobile application of the digital children's booklet.

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The forms show the section for the registration of infant data, as well as the information on the immunisations that are available, the diseases that prevent each one of them and the dates of application in order to notify parents in a timely and clear manner.

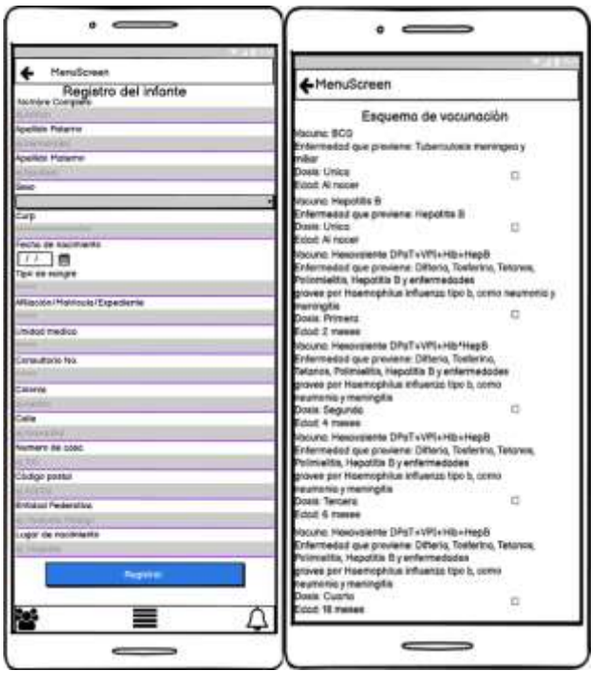

Figure 8 Sketch of the graphic interface of the mobile application

For the coding of the interfaces of the mobile application, it was developed in a Framework (React Native), using a code editor (Visual Studio Code), designing the application with a library (React Native Paper). For the functionality of the application, it was connected to a non-relational Mongo DB database to process the data registered by the user.

Figure 9 shows the appearance of the forms at the end of development and a unit test performed.

Figure 9 Graphical interface of the mobile application

The end-user acceptance tests were conducted with the intention of verifying that the different modules of the mobile application work according to the needs established in the initial requirements of this research.

Figure 10 presents the results of the parent and infant registration test; these were satisfactory and in accordance with the requirements.

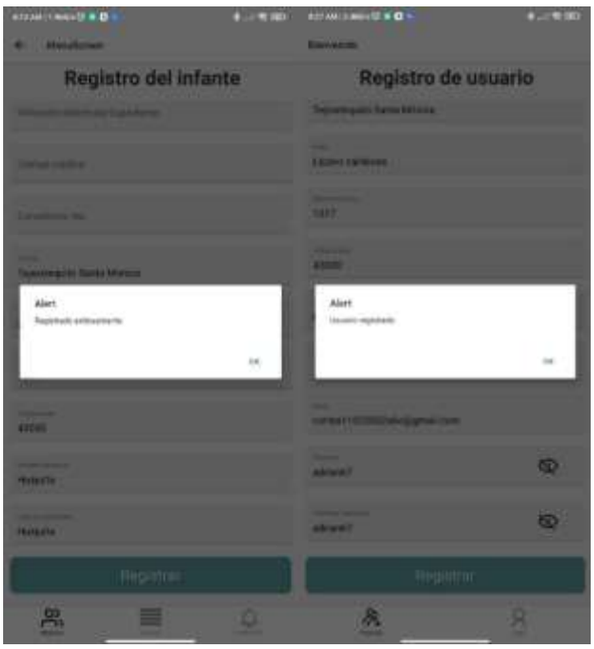

Figure 10 Test registration of Father and Infant

Together with the prototype of this mobile tool, the technical and user manuals are included, which are indispensable for the updating and extension of future functions foreseen for this project.

Results

During the phases of the development of the "Prototype of a mobile application for monitoring child vaccination", each of the processes necessary to obtain the prototype in the estimated time were analysed. The expected results for this project were very successful as the delivery of a prototype for this tool was achieved.

In the first instance, information was gathered on the needs of the medical units located in Health Jurisdiction No. 10, with coverage in the municipalities that make up the Huasteca region of Hidalgo, which reported the problems related to the difficulties in carrying out the application of biologics to infants, mainly because the publications related to vaccination campaigns were not sufficient in terms of coverage within the population.

In the same way, information was obtained from the health authorities regarding the inoculations that include child vaccination cards and the dates of application of each one of them.

Once the main need was determined, it was determined that a mobile application was the best option to solve the problems, largely due to the fact that people who have a mobile device have the possibility of receiving personal notifications with information regarding their children's health.

Next, once the necessary requirements were established, it was determined that Extreme Programming (EP) would be used to develop the prototype in question, as it is a methodology that adheres to agile development.

We started with the creation of the user stories (UH), which would be the essential foundation for the creation of the mobile tool's modules. Subsequently, the sketches of each of the sections were designed to create the functions of the software from the user's point of view. The designs had the characteristic of being practical and pleasant for the beneficiary.

Within the coding, the integration of the increments was carried out through the specification of sprints. The forms that make up the graphical user interface were developed using different programmes such as Visual Studio Code, JavaScript in the React Native Framework and Mongo DB as a database administrator.

The unit tests were applied correctly, using Expo as a framework that operates on React Native, in order to be able to run the application and observe the changes that were being made. Also, database registrations were done properly, sending the data captured in each of the forms.

The elements of the graphical user interface met the usability requirement in the acceptance tests, where the user interacted between screens easily and quickly, having a very pleasant environment for the user contemplating a palette of appropriate colours for the user.

Conclusions

The mobile application is intended to have a great impact on society, as it will help many parents to avoid forgetting the dates set for their children's vaccinations. The development process of this project was based on the Extreme Programming (EP) methodology, because it follows a strictly rigorous order of the stages for the implementation of the mobile application.

In the planning stage, the problems were identified and the objectives, goals and characteristics of the development of the mobile application were determined; the requirements to carry out the project and perform the activities described in the user stories were also analysed.

For the design, the sketches of the graphic interface were created, the sketches of how the application sections were planned to be visualised, the forms together with their respective backgrounds and user-friendly colours.

Coding involved the development of the established designs, inclusion of the colour palette, ensuring that the functionalities adhered to the established needs; all of this was supervised under unit tests that ensured the correct functioning of the prototype.

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Finally, the acceptance tests were successfully applied, resulting in a practical and easy-to-use tool that meets the expectations of the end user.

As a proposal, the extension of functionalities is established. In this first stage, this digital immunisation booklet is intended to be a notification tool for parents about the dates and vaccines available for their children, but it is considered to add other functionalities that will allow health personnel (doctors and nurses) to carry out complementary actions to child vaccination campaigns.

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