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Collaborative desing in web aplication development to improve tuberculosis diagnostic

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ABSTRACT

In Peruvian Tuberculosis Reference Laboratory of the Regional Health Directorate of Callao, issues related to the diagnostic process where identified, because of the slowly generations of patients result. This research develops a web application to solve these issues using a participatory design. Qualitative data were recollected through interviews and focus groups in 45 medical centers belong to the regional health directorate (DIRESA) from Callao. These data were used to define the correct design and develop the required processes in the web application. Quantitative data were recollected either, to measure the efficiency of the new diagnostic process using the web application. The results show that with the use of the web application 120 hours were reduce from the monthly validation results and avoid the generation of 8,700 duplicate information, with these results the diagnostic process was improve. The research also confirms that the design and use of technological tools in a collaborative environment improve the process efficiency.

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1. INTRODUCTION

Tuberculosis still have a major percentage of death causes worldwide, where young children has the highest risk of infection [1] for this reason is required improve the diagnostic and treatment, health's applications has an important contribution to improve tuberculosis treatment as in mention on [2], [3]. In general not only the use of health's applications on tuberculosis treatment has increased, the use of health's applications growing in many health areas. Many system were implemented as a personalized web-based health applications to improve treatment and diagnostic [4]. Some of these web-bases technology are related to: diagnosis of tuberculosis, tele-radiology, laboratory information management systems, electronic patient records, patient tracking systems [5]. This web-bases technology are applied in different areas to solve many importan problem like control the non-adherence to treatment and analyze the multi-drug resistance using technologies pillboxes and video directly observed therapy [6]. In that context web applications has a great support for the health sector, correctly oriented and can be used to solve any Public Health problem. For example, the National Institute of Health (INS) in Peru implemented an information system called NETLAB that has as a main objective the surveillance of public health. This web application solved the problem of managing laboratory test results that

required a lot of time for their preparation. Since the implementation, NETLAB has optimized the management of the laboratory service in the INS, reducing the time response of testing requirements, achieving enormous savings in time and material costs [7].

A digital solution for the maintenance and distribution of guidelines and standard operating procedures (SOP) were implemented in the Department of Anesthesiology and Pain Medicine at the Kantonsspital Lucerne in Lucerne and in the Department of Anaesthesiology and Pain Medicine of the Inselspital in Switzerland this kind of system is important and gives support to the daily clinical routine, this investigation evaluated the systems' impact by analyzing content and usage, after one year of usage the system was accepted and appreciated by the users made the daily routine easier, it shows that web-based solutions could be an important tool to handle guidelines and SOPs in hospitals [8]. Health care is changing focusing on patient-centeredness. Medical appointment scheduling, is the starting and important point, many times this first step is slowly and not efficient, many patients has to wake up early and make a long rows to setup and appointment, by using a web system over internet as a medium, the patients avoid this problems and gain freedom to choose their preferences for the appointments. For identify the benefits of implement Web-based medical scheduling systems 36 articles were reviewed as a result the main benefits obtained were, decreased staff labor, decreased waiting time, and improved satisfaction, and so on. Cost, flexibility, safety, and integrity [9].

A formal definition of tuberculosis is a bacterial disease caused by the germ called Mycobacterium tuberculosis, which mainly attacks the lungs [10]. Symptoms may include severe cough, weight loss, coughing and spitting blood, weakness or fatigue, fever, the usual contagion is by air when coughing, sneezing, laughing, singing or talking [11]. Despite medical and technological advances in the control of tuberculosis, it is still considered by the World Health Organization (WHO) as a deadly disease in underdeveloped countries [10]. In Peru, tuberculosis is one of the diseases with the highest morbidity and mortality. That is important reason of implementing tools for better diagnosis and care for the tuberculosis patient. The problem described was also identified in the Tuberculosis Reference Laboratory of the regional directorate of health of Callao (DIRESA Callao). DIRESA Callao, this laboratory performs diagnoses on microbiology of non-profit tuberculosis, its mission is the prompt response of baciloscopy results, solid cultures and drug susceptibility tests through microscopic observation drug susceptibility (MODS), of the samples of patients who come from the 45 health centers of DIRESA Callao, among them we can mention the Daniel Alcides Carrión del Callao National Hospital (HNDAC), Hospital de Ventanilla, Hospital San Jose del Callao, Hospital Naval, Hospital Alberto Sabogal Sologuren ESSALUD [12].

Due to the importance and large number of medical centers served by the laboratory, there is a great demand for samples from the establishments, from approximately 15,000 to 17,000 samples per year. In 2015, an agreement was reached in the Tuberculosis Reference Laboratory that the activities of recording patients' samples move from the reception book (manual registration) to a calculation file called the bacilos copy database, to facilitate data processing, but due to lack of personnel, time, training and experience in the program, an optimal result was not achieved. The use of this new data collection method generated problems of alteration of information, which causes a re-entry of data and reveals the lack of security controls for the data. The diagnostic process of the Tuberculosis Reference Laboratory has activities like the registering patient samples process. The reception staff enters the sample information in a spreadsheet; the samples that will go through the MODS analysis are selected and the patient information is recorded in the MODS selection report and in the MODS internal result control report. These repetitive activities during the register of sample information delay the process in two hours. The preparation of sample results reports, and MODS analyses is a primary activity for the Tuberculosis Reference Laboratory, which allows to know the reality of the laboratory and allows decision-making to implement new improvement strategies in the laboratory, this elaboration process also requires a time of two hours and delay the process.

This research covers the stages of determining the problem, requirements, acceptance criteria, he design and implementation of the web application using a collaborative work environment using agile methodologies. Our contribution seeks to answer the following research questions:

- RQ1: How to improve the activity of registering bacteriological applications on the diagnostic process of the Tuberculosis Reference Laboratory?
- RQ2: How to prevent the manipulation and alteration of sample information and diagnostic results of the Tuberculosis Reference Laboratory?
- RQ3: How to reduce the preparation time of the reports and indicators issued by the Tuberculosis Reference Laboratory?

The proposed solution is implementing a web application for help the diagnosis process, the use of information technology (IT) in the process of tuberculosis diagnosis, is currently used as its seen in the research [13] titled an intelligent mobile-enabled expert system for tuberculosis disease diagnosis in real time. The developed system use images and a processing technique for analyzes the contents of plasmonic ELISA. for this research a supervised machine learning techniques were implemented for determined de correct classification of images and determine illness patients. One of the most challenging activities in this research was the images extraction and analice their features. The system was implemented using a mobile device and the accuracy obtained was 98.4 percent.

Another use of IT for tuberculosis diagnosis is the research [14] a fully automatic artificial intelligence–based CT image analysis system for accurate detection, diagnosis, and quantitative severity evaluation of pulmonary tuberculosis; In this research, this articule develop an artificial intelligence based on image analysis for detection, diagnosis of tuberculosis. A chest scans for patients with tuberculosis were realized from December of 2007 to September 2020 with a 892 total scans. Using a deep learning algorithm the data was labeled in six critical categories for create and train de model. As a result the model can identify the patients with lung lesion causes for tuberculosis with a mean average precision of 0.68. Respect of investigations in Perú the [15] implementation of a tuberculosis tele-diagnosis system and determination of multi-drug resistance bases on the MODS method in Trujillo, shows that the use of tele-diagnosis in remote places, collaborates in the detection of tuberculosis and multi-drug resistance (MDR), using the MODS method in the Tuberculosis Laboratory of Trujillo, was developed with a recognition algorithm Mycobacterium tuberculosis obtained from digital images of MODS. Resulting that sensitivity and specificity in objects were 92.04% and 94.93% and sensitivity and specificity in photo were 95.4% and 98.07%. The research exposed improve the tuberculosis diagnosis using IT, the solution proposed in this research is related to improve the administrative control of tuberculosis' test and patients' information.

2. METHOD

2.1. Scrum methodology and participatory design

A software methodology is a defined steps to build software applications, in which tasks, artifacts and relations are identified. This permits an organized process of development through the definition of good practices and restrictions to meet [16]. One of these methodologies are agile methods, this type of methodology allows modifications in the planned work to adapt to the change's environment of the project, obtaining flexibility and immediacy to the changes, also allow work in a collaborative environment with many interactions among stakeholders and project team. Scrum is one of the most important agile methodologies and apply a whole of good practices to work collaboratively with constant feedback from stakeholders, and this help to get best possible result in the project. The characteristics of scrum are the following: adaptability, transparency, continuous feedback, continuous improvement, continuous delivery of value, sustainable pace, advance delivery of value, efficient development process, fast and collaborative troubleshooting, highly trusted environment, collective responsibility, innovative and sustainable work environment [17]. The implementation of scrum needs to follow some steps, begin with a meeting with the main stakeholders to develop the vision of project. After that a list of prioritized requirements is elaborated (backlog). The requirements will be built in a short period of development called sprints with maximum 4 weeks of duration. The product owner is responsible of keep the backlog updated bringing a maximum value to the business. The requirements inside the backlog are called user stories. Each sprint starts with a planning meeting, high priority user stories are selected to develop during the sprint according to the team velocity. During the sprint daily meetings are performing to discuss the daily progress. After the user stories are concluded a validation meeting is set to show the deliverable to the product owner looking for the approval. The sprint finish with a retrospective meeting where the team is looking for improve their work and performance for the next sprint [18].

2.1.1. Backlog creation and estimates

Interviews were conducted for each medical center which belong to DIRESA Callao also to the laboratory personal with an average of 50 persons who participate to identify the problems. They participate in individual interviews and focus groups for validations to confirm the problems and identify the main requirements needed. During these meetings a main stakeholder was selected as a product owner who allow centralize validations and improvements identified for all stakeholders which permit a collaborative work.

2.1.2. Data collection and system analysis

For identification of requirements of the web application two focus group were performed using techniques like brainstorming and prioritizations, in the first focus group high level requirements were identified named user epics [19], after that in the second one the user epics were detailed turn into user stories needed to perform the elaboration of the web application. In these focus group the participants were divided in groups of 5 at the beginning among them could identify ideas for the requirements for that used the round robin technique, grouping in circle and pass through them a token, the person who had it give an opinion and pass the token to the next person who complement the opinion to build a collaborative idea. After this first part the groups share their ideas to the whole audience and receive feedback and identified both the user epics at first and the user stories later, as a result a high-level story map where develop for the epics (Figure 1) and a pruning the tree for the user stories these are agile techniques for requirements identifications [20].

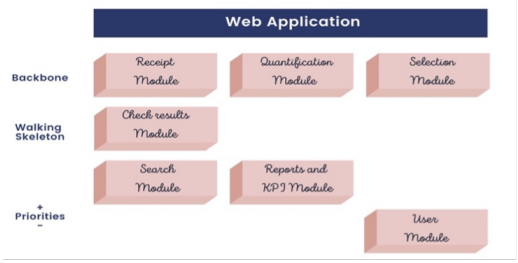

Figure 1. User epics map

The high levels requirements (named user epics) identified were, user module, for user administration, define roles and control user logins. Receipt module, for records samples for laboratory tests. Quantification module, for controls the quantity of patients' samples. Selection module, for determines the tests that will be carried out on each sample. Check results module, for verification of the patient results. Search module, for search information by patient and medical establishment. Reports and KPIs module, for visualize and evaluate statistical indicators that will help decision-making. For demonstration and evaluation of the developed modules constant feedback were required this was possible because the agile methodology scrum was used so during the sprint execution an active collaboration and communication with the product owner and stakeholders were performed, even yet when the sprint was over a formal meeting named sprint review were performed to obtain the formal product owner and stakeholder approbations. The improvements of the process by using the web application were demonstrated with quantitative data collection measuring the time of the process before and after the use of the web application for determine the efficiency this result in detail is commented in the discussion and result section of this document. Additionally of the collaborative work realized traditional collection of information were realized for determine the documentation needed to incorporate in the web application many of this documentation is required by Peruvian laws. The documents recollected are in the following list: formats of applications for bacteriological research, bacteriological application charges, application rejection notebooks, spreadsheet application database, results quantification sheets, selection registration forms, MODS process sheet, production indicators from all laboratories, MODS KPIs, all of them were needed to determine the information required that had to be unified inside the web application.

2.2. System design

In this section the considerations that were taking account for the web application development and design will be explain. After all the requirements were identified and converted in user stories using agile collaborative techniques more detail is required this detailed characteristic of the user stories were defined in the initial process of planning and estimate of the project [17]. This process include the backlog creation in which step the user stories are prioritized and estimate by the product owner and the project team. This process is described in the next sections.

2.2.1. Backlog creation and estimates

The project backlog is an agile artifact in which a list of prioritized of work is establish, this work is going to be develop during the whole project [21]. For the backlog elaboration detailed user stories need to be identified that permit to know the real dimension of the work needed and allow realize a correct prioritization

and estimation of the work. After determining the user epics and realize pruning the tree techniques [20] 45 user stories were identified, the identification of these user stories was realized with the participation of the product owner, final users, and development team. The user stories identified need to be prioritize according to the value they bring to the laboratory to improve the diagnostic process. For that the one-hundred-point prioritization technique were use the technique belongs to gaming prioritization techniques group [22]. One hundred point were given to all participants, and they must distribute the points for all user stories, the ones get the higher score were the more most valuable, so they are in the top of the backlog. The next activity performed were the estimation of user stories, in agile methodologies the estimation is using relative metrics that allow focus the estimation in determine the required effort for the user stories, the metric used were story points the key point of using relative metrics is make them comparable to each other it makes the user stories easy to compare by required effort [23]. Planning poker was the technique used to the estimation this technique promotes a collaborative environment [24]. The responsible to make the estimation were the development team because the team has the required expertise to determine the effort needed for each user story. In this technique a game of card are given to the participants, this card are numbered by the Fibonacci series (as a good practice), one of the participants read a user story and make an explanation about the functionality, the rest of participants ask about doubts they have about the story, after that make a vote, if the vote is similar them an agreement is set, if don't explain the story again until everyone has a fully understand of the story and vote again, to set an agreement. This process is repetitive for all user stories and finally all the stories get their respective story points. At the end of the estimation the backlog had 214 story points, with these points the number of sprints must be determined, for that, the team determine their velocity and the time required for each sprint (4 weeks per sprint), the team velocity is defined by the number of stories points the team can perform during a sprint [21]. The initial team velocity was 33 story points per sprint, it means that the team can develop stories that sum 33 points and it give 7 sprints required to build the application. In Figure 2 a product roadmap is created (user story level), this tool shows us the path of development the web application divided by sprints and by the minimal viable product of the application located in the backbone and walking skeleton sections [25].

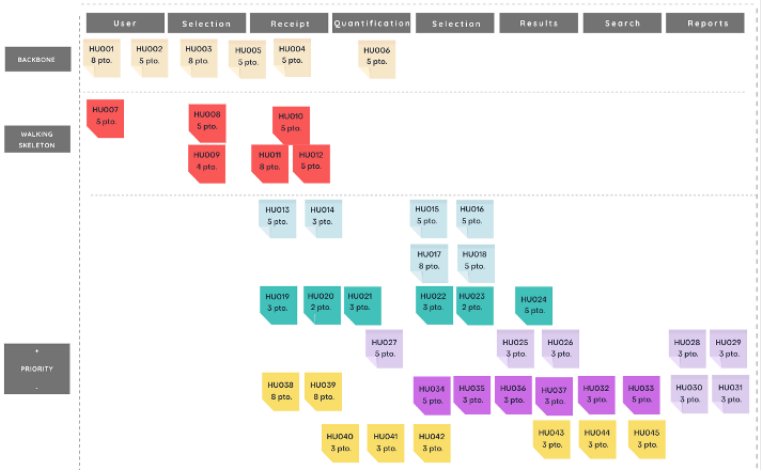

Figure 2. Product roadmap

2.2.2. Sprints planning

In agile methodologies the approach for planning is just in time, it means just plan in detail what is going to need to develop soon, in this case is just plan the first sprint, the user stories to develop in the first sprint are in the backbone section of Figure 3, the user stories to develop in the sprint are named the sprint backlog [26]. The first sprint objective was: manage solicitations, verify the status of the samples, and register bacteriological tests assigned to each sample, for planning key stakeholders and product owner explain the details of the stories to confirm the definition of done about them [27]. After confirming the definition of one the development team establish the activities and tasks needed to build the user stories and meet the acceptance criteria defined. Agile methodologies are focus in bring value to the business and don't make a lot of documentation about the requirements, the user stories has three characteristics named the 3Cs [20], the first C is the card that is remember of what the story means, for this research a virtual card was used (using

software Trello), the second C is the contract and is because the card represents a remainder of a contract with the product owner defined on it the acceptance criteria for the story, the last C means the conversation because any additional detail should be work and defined with the development team, product owner and stakeholders, in Figure 3 an example of a Trello card and their corresponding acceptance criteria is show.

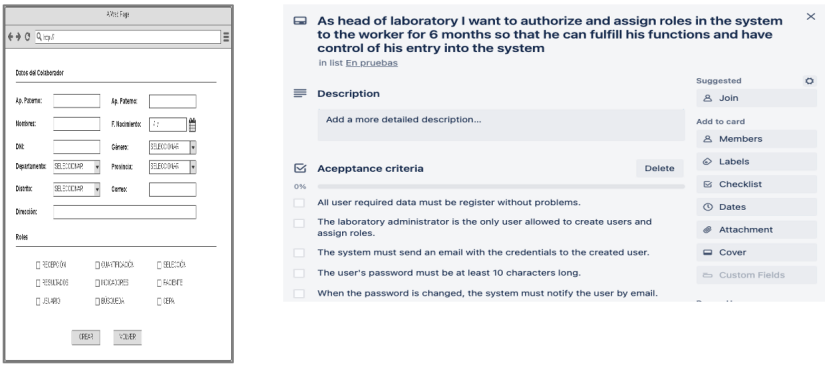

Figure 3. User history design/card

3. RESULTS AND DISCUSSION

3.1. System design results

The stories validation and designs were made progressively after each sprint in the sprint review [28]. On this meeting the development team, product owner and stakeholders accept the user stories functions, the team show the compliance with the agreed functionalities and with the acceptance criteria and let stakeholder use the system in usability tests. After this meeting the approved user stories are ready to implement and use by stakeholders, and the following user stories should be elaborated in the next sprint.

3.2. Discussion

The discussion of the results is organized according to the research questions identified.

RQ1: How to improve the activity of registering bacteriological applications on the diagnostic process of the Tuberculosis Reference Laboratory?

- The reception module was implemented to centralize the registration of the bacteriological application. Resulting in the following:
  - i. The number of collaborators who registered bacteriological requests was reduced from 3 to 1, due to the ease of entering the data into the system.
  - ii. Activities that doubled bacteriological applications (1450 applications per month on average) that were registered by 6 collaborators were eliminated, with a total of 8,700 duplications avoided.
  - iii. The re-verification of applications and bacteriological results that consume 120 hours per month was eliminated.

RQ2: How to prevent the manipulation and alteration of sample information and diagnostic results of the Tuberculosis Reference Laboratory?

- In accordance with the principles of information security, the following measures were implemented to prevent the manipulation and alteration of information:
  - i. Integrity: audit columns were implemented in the database tables. States were established for the different phases of the laboratory process to control the information entered, the last state is ”Finished”, which leaves the information in read-only.
  - ii. Confidentiality: the user account module has been successfully implemented, which allows efficient management of the creation and assignment of permissions in user accounts.
  - iii. Availability: a backup is made every day at 9:00 p.m. It is monitored that the server is available 24/7.

RQ3: How to reduce the preparation time of the reports and indicators issued by the Tuberculosis Reference Laboratory?

– The reporting and KPIs module were implemented to reduce processing time. Time measurements were made with respect to the preparation of reports, resulting in the preparation process being reduced from two hours to two minutes.

4. CONCLUSION

The conclusions of this study in which the development of a web application was carried out to improve the process of diagnosis of tuberculosis using a collaborative methodology for the identification of the problem and for the elaboration of the design managed to meet the main objective that is to improve the care processes that collaborate with the diagnosis of tuberculosis, being able to reduce times through the improvement of care processes supported by the use of technology that In addition, by carrying out the construction of the application through a collaborative and participatory work environment, it was possible to design and build a fully functional web application that helps significantly with the improvement of care processes in general. However, in view of the continuous advance of technology and hospital processes, it is recommended to have an information technology staff who constantly checks the changes that may exist in the care processes so that these can be implemented in the web application and thus continue with the continuous improvement of technological processes and tools.

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