ELECTRONIC VISION

Design and implementation of a web platform for student tracking and notification using sms and E-mail

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Abstract

This paper presents the design and implementation of a web platform for student tracking and notification using SMS and email (at a school called Instituto San Francisco (Bogotá,Colombia). Firstly, the document addresses the needs of the school, which represent the main concern for this academic web platform. Subsequently, this paper shows the analysis of technologies and describes the design of the platform based on the requirements of the institution. Additionally, the web platform performance analysis and testing results are included. Finally, results of implementing the academic web platform at Instituto San Francisco are provided together with the conclusions and recommendations drawn at the end of the project.

Key words

ICT, platform, SMS, Web, email, performance.

1. Introduction

The educational process of young students requires, as a fundamental element, the presence of the family, which, in the locality of Ciudad Bolivar, commonly consists of unmarried women or other family members (granparents, uncles, brothers or sisters) [1]. In this context, educational institutions are becoming the main entity in charge of providing formation for this young people. Thus, educational institutions are facing new challenges associated to facilitating community interaction and so ensure permanent support for pa-

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rents and teachers, pursuing the growth and development of children at Ciudad Bolivar.

In order to cope with this situation, the present project is aimed at promoting strategies that allow improving the quality of education, especially for young people (attending school) in Ciudad Bolivar. The core of the project is based on the use of ICT to facilitate the learning process and provide tracking information about youngsters.

The web platform, implemented at San Francisco School, allows tracking the educational process of students and its main objective is to promote the participation of parents and teachers in this educational process. Thus, the platform is intended to reduce the probability of young people getting involved in the intricate social problems that affect Ciudad Bolivar.

At this moment, these problems are growing, thus it is pertinent to introduce new technological solutions that help to overcome the difficulties that an educational institution may face in the educational process of young people.

Nowadays, software development projects intended to be applied in a LAN (Local Area Network) environment allow automating administrative, academic and management processes. The objective of the present software application is to manage internal processes and facilitate the communication between parents, students, teachers and staff. There are available options such as DocCF – student management software [2] – which consists of modules such as: student management, teacher management, grade management, financial management and library management.

SIGA (Integrated System for Academic Management) [3] is another option of educational software available; it uses specific modules for tracking students, teachers, schedules, inventory and access control.

Other solutions include implementation of academic management in a public infrastructure through services like hosting, facilitating the access to an automatic tool that integrates the whole academic community. There are tools with this characteristics, like WPCA (Web for schools) [4], which consist of a management and communication service designed for academic institutions; where the students, teachers and parents can interact to achieve a better academic performance.

There is another tool, called Clickedu [5], which is oriented to educational institutions. This tool combines the organizational school tasks in an environment intended for the learning of ICT from the school.

2. Analysis of Communication Needs

The platform design is oriented to an analysis of needs at the school, where communication problems between parents and the local community in general were detected. This analysis used several tools such as interviews to school staff and surveys to the academic community.

As a result of this analysis, the following problems and limitations were found:

- Effective communication media, like mobile phone calls, have a high cost due to inter-operator rates in cellular services.
- The institution does not have a web site or electronic media to report to the academic community about its educational offers, activities, etc.
- The parents have little contact with technology, because some people do not have access to the Internet or to a computer. Thus,

some of them prefer to receive notification about their children's process via SMS.

- The academic community acknowledges that a web platform does not substitute the basic communication media, but it can be a supporting tool for people with time constraints.

3. Platform Design

For the web platform design it is necessary to analyze the different choices in terms of available technology for content management, databases, and data-management web applications that may handle multiplatform languages such as PHP or SQL [6]; thus the most adequate option can be selected according to the platform requirements and the initial design.

A technology analysis and evaluation over the available tools is performed. To this end, several aspects were considered, e.g. easy-to-use and easy-to-manage features, costs, potential providers (vendors), the position in the market, technical support, and compliance with the objectives and requirements of the institution. Table 1 shows the quantitative/qualitative values used to qualify the technologies:

Table 1. Technology Qualification

QUALIFICATION	
Yes, Low, Possible, Excellent	3
Medium	2
No, High, Not possible, Poor	1

Source: own elaboration

For the web page type selection, Table 2 indicates the parameters that were evaluated:

Table 2. Web page design qualification

Parameter	Dynamic Web	Static Web
Content updates, graphic design, ease-to-manage, access speed	Yes	No
Easy-to-use	Yes	Yes
Personalized professional design	Possible	Not Possible
Better interaction between user and web interface	Excellent	Poor
Cost	Low	High
Functionalities (databases, forums, contents)	Yes	No
Open-source software	Yes	No
Predesigned solutions	Yes	No

Source: own elaboration

The evaluation results performed over the web page design are presented Table 3, where it is suggested that the best option to be implemented is the dynamic web page.

Table 3. Web page design evaluation

Parameter	Dynamic Web	Static Web
Content updates, graphic design, ease to management, access speed	3	1
Easy-to-use	3	3
Personalized professional design	3	1
Better interaction between user and web interface	3	1

Costs	3	1
Functionalities (databases, forums, contents)	3	1
Open-source software	3	1
Predesigned solutions	3	1
Evaluation Total	24	10

Source: own elaboration

The same methodology is used for all components involved in the web site development [7]. Regarding content management, the parameters listed in Table 4 were evaluated:

Table 4. Content manager evaluation

Technical Parameters	Content Managers		
	Plone 3.0	Joomla 1.5.22	Drupal 6.10
Free of charge	3	3	3
Open-source code	3	3	3
Security			
e-mail verification	3	3	3
Login history	1	3	3
Session management	1	3	3
Functionality and design			
General (portal, magazine or store)	3	3	3
Development level	2	3	1
Technical architecture	2	3	3
Market share	1	3	2
Download speed	2	3	1
Evaluation total	**21**	**30**	**25**

Source: own elaboration

For LMS (Learning Management System) evaluation, the criteria to be evaluated included (among other aspects) security, easy-to-use features and added functionalities, the resuls of this evaluation can be observed in Table 5:

Table 5. LMS Evaluation

Technical parameters	Academic content manager		
	Atutor 1.5.3.3pl1	Caroline 1.5.1	Moodle 1.9
Cost	3	3	3
Open-source code	3	3	3
Security			
e-mail verification	3	3	3
Login history	3	3	3
Session management	3	3	3
Design and functionalities			

Web tools (tasks, forums, wiki, surveys, etc.)	2	1	3
Easy-to-use	2	2	3
Market share	1	2	3
Email reporting	3	3	3
Plugins			
SMS module	1	3	3
Evaluation total	24	26	30

Source: own elaboration

The selection of the SMS sending method [8] focuses on selecting the most suitable technology to address the needs of Instituto San Francisco. This evaluation is listed in Table 6:

Table 6. SMS sending method evaluation

Technical parameters	SMS sending solution			
	Web Page	SMS Integrated E-Mail	SMS Gateway	Software/Cell Phone
Costs	2	3	3	1
Vendor availability	2	3	3	2
Easy-to-use	3	2	3	3
Configuration complexity	3	2	2	3
PHP/HTML application compatibility	1	3	3	1
Moodle integration	1	1	3	1
Hardware adquisition requirements	3	3	3	1
Maintenance	3	3	3	1
Evaluation Total	18	20	23	13

Source: own elaboration

As a result of the evaluation of all components, Table 7 summarizes the selected technologies:

Table 7. Web platform technology design analysis

Item	Evaluated Options	Selected Option
Web Page	Dynamic Web	X
	Static Web	
CMS (Content Management System)	Drupal 6.10	
	Joomla 1.5.22	X
	Plone 3.0	
LMS (Learning Management System)	Atutor 1.5.3.3 pl1	
	Caroline 1.5.1	
	Moodle 1.9	X
SMS sending method	Web page	
	Integrated E-mail	
	SMS Gateway	X
	Software /Cell Phone	

Source: own elaboration

For the infrastructure dimensioning intended to support the platform, the selected technologies were analyzed considering their requirements and the expected users. Regarding this information it was suggested that the web application should be deployed over a server in a sharing hosting fashion. The hosting features include the software versions presented in Table 8, which can support all the functionalities of the web application:

Table 8. Web application software

Operating System	Linux (Vanilla 2.6.18)Versión de Kernel: 2.6.18-194.17.1.el5xen
Management application	cPanel 11.28.83
Web server	Apache 2.2.14
Database server	MySQL 5.0.84-percona-highperf-b18-log
PHP version	5.2.14
Joomla	1.5.22
Moodle	1.9

Source: own elaboration

In the application development the use diagrams are defined according to the user roles that interact with the application [9], namely parents, teachers, students and a web administrator. The diagrams define operations on the application, such as student tracking with Mentees profile and the use of an SMS communication module.

The use diagram defined in Table 9 and Figure 1 refers to the functionality of academic tracking performed by parents.

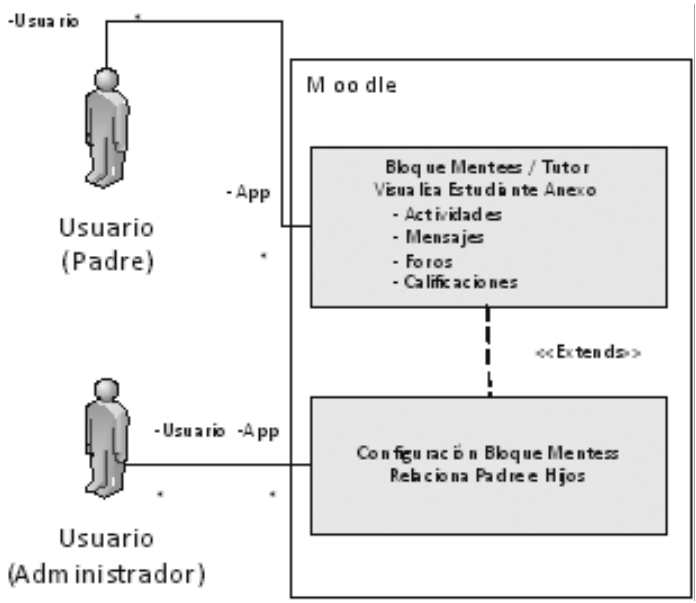
The second use diagram is defined in Table 10 and Figure 2. This diagram illustrates an SMS sending functionality.

Table 9. Module Mentees use diagram description

Student Name:	
Student tracking by module Mentees tutors	
Date:	23/02/2011
Description:	
Perform tracking by tutor or parents to the student	
Actors:	
User logged in using parent profile	
Preconditions:	
The administrator previously related the student profile with parent	
Normal flow:	
1. Login in the application using the parent profile 2. The actor locates the module on the right, named Tutor, and the link appears there with the student's name 3. Click on the student link to access the related information 4. Access a new page with activities, messages, forums, grading.	
Alternate Flow:	
5. Logging in as parent user, notice that there is no tutor or more than one assigned, this configuration must be allowed by the administrator	

Source: own elaboration

Figure 1. Use Diagram: Mentees Module



Source: own elaboration

Table 10. SMS/e-mail communication use diagram Description

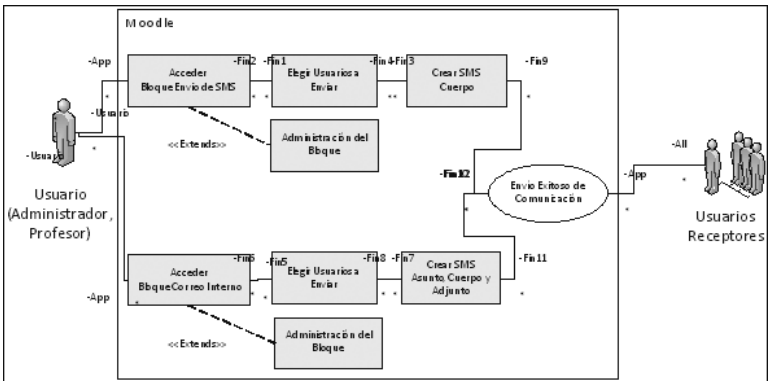
Name:	SMS/e-mail communications
Date:	23/02/2011
Description:	
SMS and/or email sending communicating news or events	
Actors:	
Users with administrator privileges (administrator, teacher)	
Preconditions:	
Keep an active account with the SMS provider	
Normal flow:	
1. Locate module for SMS sending and internal email 2. To send a SMS, click on Enviar, then choose the destination users and finally fill in the message body 3.Click on Enviar to send the SMS 4. To send an email, click on Bandeja de entrada, write the message body, then choose the destination users, fill in the Subject and body fields 5. Click on Enviar to send email	
Alternative Flow:	
5. If the user fails to enters a phone number field, he/she would not be allowed to send the SMS	

Source: own elaboration

3.1 Web page composition T2

Initially, Instituto San Francisco's web page is to be designed. This web site is to be taken as the presentation image of the institution on the Internet. From this web site, is possible to access email accounts and the Moodle academic management platform [10]. The features of the web page are detailed in Figure 3 and Table 11:

Figure 2. Use Diagram: SMS/e-mail communications



Source: own elaboration

Figure 3. Web site header – Joomla

Source: own elaboration

Table 11. Web page header-Joomla Description

No.	Element	Description
1	General Logo	Instituto San Francisco JPG image logo
2	Gallery	Link to school photo gallery
3	Search engine	Search for contents inside the web page
4	Main Menu	Drop-down menu listing hyperlinks
5	Slide Show	Component that slides images within a 30 sec interval, between transitions it shows articles related to sliding images
6	Message of the day module	Information module regarding the academic community (shown at random)

Source: own elaboration

The web page body includes the features mentioned in Figure 4 and Table 12:

Figure 4. Web page body-Joomla

Source: own elaboration

Table 12. Web page body-Joomla Description

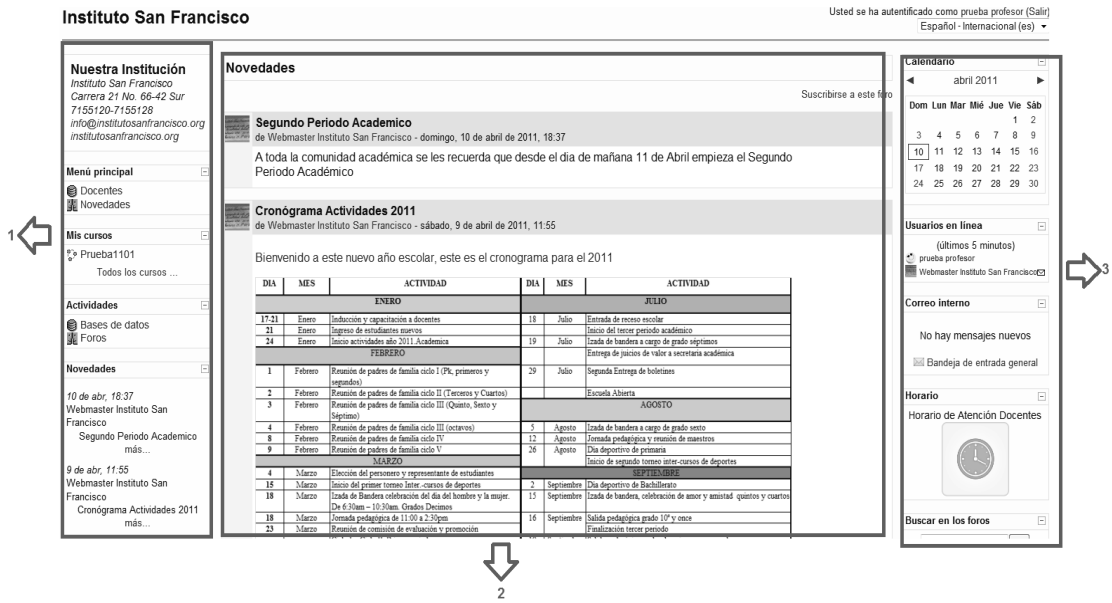
No.	Element	Description
7	Articles	Reserved space in the web page to publish articles or school information
8	Menu	Main Menu located in the web page body, it is the same menu that is located in the header, but without the hyperlinks, showing all the information
9	Management button	Button linked to the academic management platform
10	Information menu	Educational information, related links

Source: own elaboration

3.2. Moodle Platform Composition

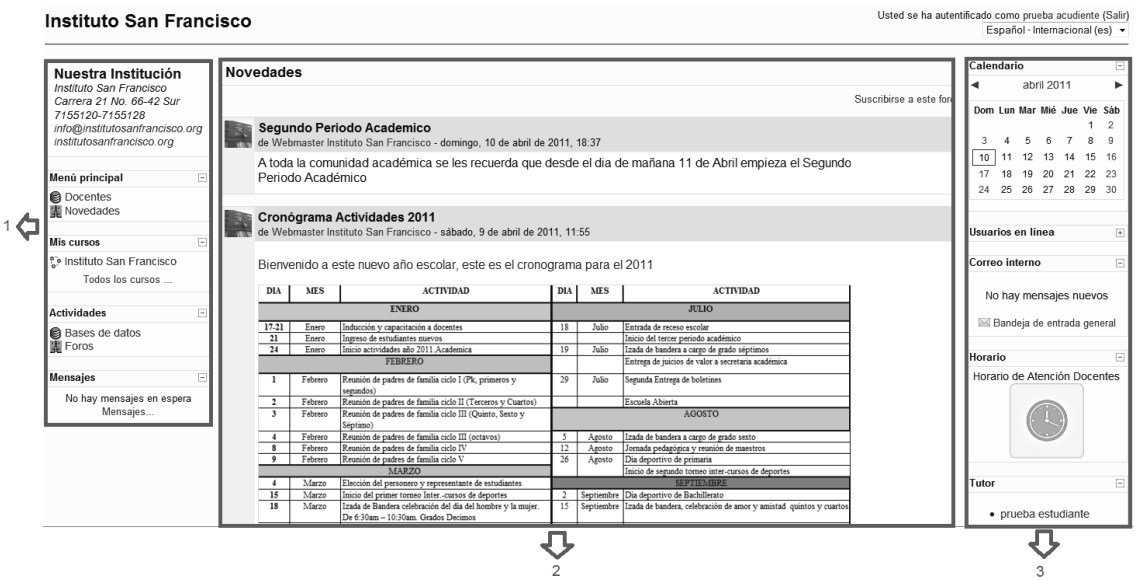
The second part of the platform is defined as the management tool (Moodle). The following provides explanations of the main components regarding user profiles [11]. For a teacher profile, access is provided to different modules as explained in Figure 5 and Table 13:

Figure 5. Moodle dashboard for a teacher profile



Source: own elaboration

Figure 6. Moodle dashboard for a parent profile



Source: own elaboration

By logging in as a parent, access is granted to a specific module called Tutor. Through this module it is possible to track the activities of a student. The features of this profile are shown in Figure 6 and Table 14:

Table 13. Moodle dashboard for teacher profile description

Module No.	Name	Description	
1	Teacher Main Menu	Are divided in:	
		Our institution	Here, basic information about the school can be found
		My courses	From this menu it is possible to explore the currently assigned courses
		Activities	From this menu it is possible to check the current activities in which the teacher is involved, e.g. forum posting, etc.
		Messages	Here, all the messages sent by other users using this tool are shown
2	Central Menu	News	Here, all the information intended for the academic community and posted by the administrator is shown
3	Others	Forum search Menu	Search for forum using any word
		Next Events Menu	This menu works as a calendar to setup personal or group events
		Internal email	From this module, teachers can send emails to other users
		Recent Activity Menu	This menu shows all the updates since the last time the user logged in the tool
		Site browsing	It offers many visualization options, so the teacher can configure them when activating the page edition mode

Source: own elaboration

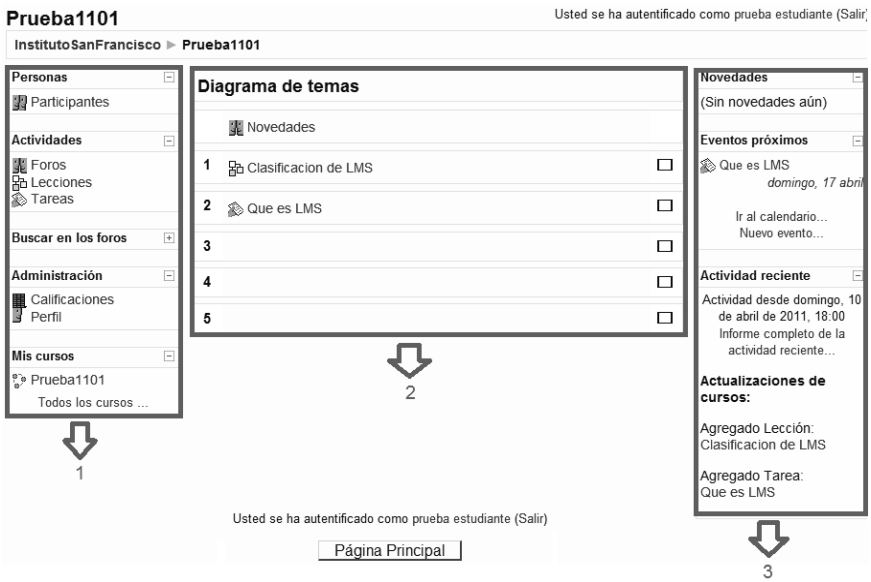
Table 14. Moodle dashboard for parent profile description

Module No.	Name	Description	
3	Other	Are divided in:	
		Internal email	From this module the teacher can send emails to other users
		Tutor	From this module, the parents can access the student's profile
		Teacher schedule	From this module the parents can check the teachers schedule and shift availability

Source: own elaboration

When logging in as a student (student profile), access is granted to all modules mentioned in the teacher and parent profile, but with different privileges. Under this profile it is possible to perform all the activities that the teachers publish in their courses, as shown in Figure 7 and Table 15:

Figure 7. Moodle Dashborad for student profile



Source: own elaboration

Table 15. Moodle Dashborad for student profile description

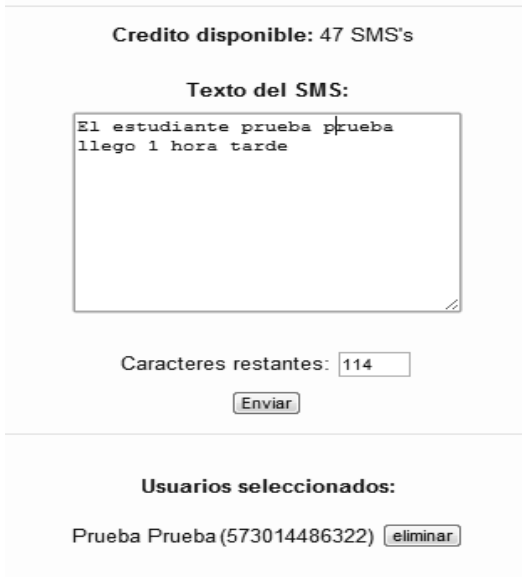
Module No.	Name	Description	
1	Main Menu	Are divided in :	
		People	From this menu it is possible to view all the course participants
		Activities	From this menu it is possible to check the current activities in which the student is involved, e.g. forum posting, etc.
		My courses	From this menu it is possible to explore the current courses to be taken (or being taken)
		Administration	From this menu the student can check the grading status of the course
2	Central Menu	Summary	The course program is shown by area or by week calendar, the student may enter and perform the programmed tasks
3	Others	Next Events Menu	This menu works as a calendar to setup personal or group events
		Site browsing	It offers many visualization options, so the student can configure them when activating the page edition mode

Source: own elaboration

3.3. Communication Module

Both the Short Message Service (SMS) and the electronic mail notification sending system make use of a module called Sending SMS Block, developed by Moodle. In order to use this module, an SMS Gateway provider [12] is required. However, no provider with PHP code integration was found in Colombia. A provider with that characteristic was located in Spain. This provider facilitates the integration with Moodle, for that reason, Dinalhosting was selected as the SMS gateway service provider. Figure 8 shows the SMS sending module used by the academic tool.

Figure 8. SMS sending module



Source: own elaboration

4. Web application performance analysis

The performance analysis for the web application to be used at Instituto San Francisco is intended to identify bottlenecks in the system, establish a baseline for future tests and identify whether the hardware infrastructure meets the requirements of the school.

For Instituto San Francisco, web application analysis entailed the following activities [13]:

- Activitiy 1. Test environment identification

The application is still under evaluation and there is no need to build a testing environment. Additionally, it appears not to be convenient to invest in a testing environment because some extra costs would be implied. Thus, since the platform is not productive at the moment, and disruption in the service is not critical yet, the testing environment is the same as the production environment.

- Activity 2. Identification of performance acceptance criteria

The identification of performance acceptance criteria of the web application for Instituto San Francisco is oriented toward validating the following aspects:

- Project vision
- System purpose
- User expectations

Regarding these aspects, and according to the staff at Instituto San Francisco, the acceptance criteria for the web application performance tests are already defined (see Table 16).

- Activity 3. Test design and planning

Within this activity, the metrics to be evaluated are defined in order to design a group of tests that allow quantifying the required information. In this case, the following metrics are defined: Number of visits per time period and web page time response.

Table 16. Performance acceptance test criteria of ISF application

PERFORMANCE ACCEPTANCE TESTS CRITERIA IDENTIFICATION	
RESPONSE TIME	**VALUE**
Web page time response	30 sec
File download time response	15 sec
Login into the management module, time response	30 sec
Browsing the management module, time response	20 sec
THROUGHPUT	
Number of concurrent users in the web page	200
Number or concurrent users of Moodle	150
HARDWARE UTILIZATION	
CPU usage	80%
Available memory	30%

Source: own elaboration

Table 17. Web application Performance analysis tools

Testing tools	Description	Requierments	Licensing
Siege	Tool for load testing and benchmarking	OS. GNU/Linux, AIX, BSD, HP-UX and Solaris	Free with registry to the developer web site
Apache JMETER	Tool for functional testing, load and performance measure	Supported in any OS	Open Source Software
OpenSTA	Tool for load testing	Designed for OS Windows	Open Source Software
WAPT	Tool for load testing and stress	Designed for OS Windows	Must be acquired through a third-party vendor SofLogica

Source: own elaboration

Within this activity, a selection of tools that allow the execution of the previously defined test plan was also carried out; in this case several options for performance tools were analyzed (see Table 17). Thus, the different features to determine the option that complies with the expectations and also with the main objectives of the test plan were validated.

The results of the tool analysis suggested Apache JMETER [14] as the most appropriate tool for testing and monitoring tasks over Apache web servers, mainly because it is specifically designed for applications installed over Apache servers; besides, this tool has many features and functionalities, offers compatibility with any Operating system and is Open-source.

Activity 4. Test Design Implementation

Three different types of tests were performed using Instituto San Francisco web application; within the tests, the following sub-activities took place:

- Baseline: consists in the execution of a group of tests that allow capturing per-

formance metrics in order to evaluate the effectiveness and current state of the web application. This data is basic to perform future tests and/or conduct additional performance analysis.

- Performance tests: these tests validate the speed, scalability and stability of an application. Within the performance tests there are two sub-categories:
    - Work Load tests: these tests focus on determining performance statistics as well as features of a particular application when experiencing a work load that is similar to the normal load to be applied in the actual production environment.
    - Stress tests: these tests focus on validating performance statistics and features of an application when experimenting work load conditions beyond the normal load. In this scenario, the test was performed with the same conditions as in the baseline test, but using 400 concurrent users instead.

In accordance with the context of Instituto San Francisco, the web application is to be designed for an expected rate of 200 concurrent users in normal conditions. Thus, the performance tests used a user rate with samples ranging from 60 and 120 up to 200 concurrent users.

Activity 5. Testing Execution

The tests are conducted over the web page, the Moodle module and the web mail module, following tests design specifications.

Activity 6. Analysis and Results Report

The results obtained in the baseline test provide evidence to state that the actual performance of the web application remains within the expected values, good response times are obtained in the range of 0.27s to 2.3s, and a moderate usage of critical resources is maintained (e.g. 40% memory and 2% CPU usage). This information provides an idea of the functionality of the platform and its resources under a normal operation conditions.

The results of the work-load tests are shown in Figure 9. Figure 9 is a report extracted directly from the JMETER tool. These tests were performed with a range of 60 to 200 users. The report offers a record of the increments in the response time of the web application, where the tendency shows that the ”School vision” hyperlink is the item with the largest delay in the application.

Regarding the server memory resource, clear progressive incremental usage can be observed. The records always show considerable memory usage when compared to CPU usage. The response times and performance indicators lie within the optimal operation range and still attain the web-application design objectives.

- Stress testing

Stress testing is performed with twice as many users as those in the latter work-load test. The objective is to verify the behavior of the web application under an amount of users that exceeds the designed capacity.

The results of stress testing, running simulations with 400 concurrent users, provide evidence to suggest that errors begin to appear in some samples (report shown in Figure 10); additionally, the response time also increases notoriously, in the range of 0.7s to 10.8s. When verifying the behavior of performance variables such as memory and CPU usage, there is evidence of sporadic peaks in CPU usage

whereas memory usage exceeds the design threshold, reaching peak values of 90% usage.

Therefore, if Instituto San Francisco expects to grow in the number of users, web-administrators must be aware that the web application can handle up to 350 concurrent users without errors; otherwise the web application will not be able to offer optimal and quality service, failing to follow the defined design parameters.

5. Traffic Analysis for SMS sending from Moodle

The size in KB of the web page in Moodle is calculated each time that the SMS sending option is used. With the Apache JMETER tool, a value of 44.799 KB is obtained.

The web hosting where Instituto San Francisco stores the web application has an internet connection of 2Mbps.

For the traffic analysis [15], the parameters listed in Table 18 were considered:

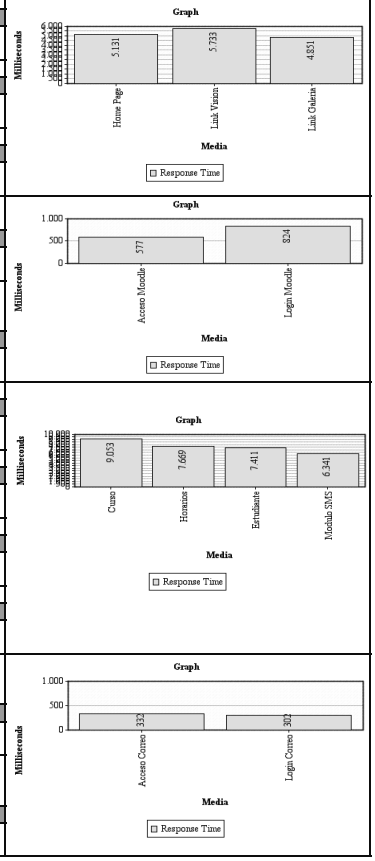
Table 18. Traffic analysis parameters

Parameter	Value
Size of the web page when configured to be sent using SMS	44.799 KB
Server internet connection speed	2000 KB

Source: own elaboration

Figure 10. Test of work load with 200 users, results report

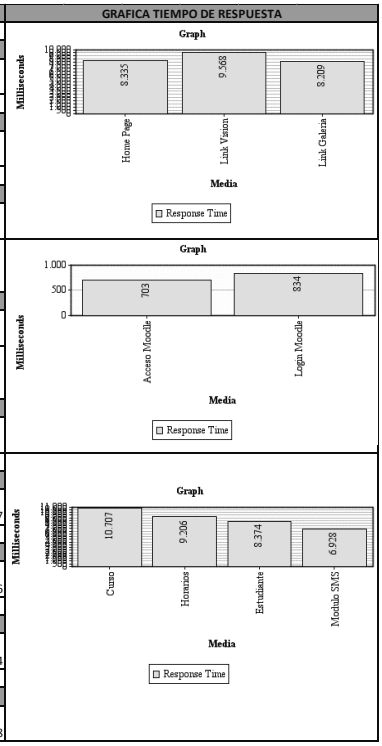
DEFINICION DE PRUEBAS				GRAFICA TIEMPO DE RESPUESTA
1. Ingresar a la pagina web http://www.institutosanfrancisco.org				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta	960	29545	5131	
2. Ingresar al articulo de Vision del ISF				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta	824	26055	5733	
2. Ingresar a la galeria				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta	498	23329	4851	
3. Ingresar al modulo de Gestion				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta (sec.)	146	11387	577	
4. Autenticarse en el modulo de Gestion				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta (sec.)	453	11096	824	
5. Ingresar a un curso				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta (sec.)	816	42976	9053	
6. Consultar el horario de docentes				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta (sec.)	458	56270	7669	
8. Consultar Hoja de Vida del estudiante				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta (sec.)	544	62489	7411	
9. Ingresar al modulo de envio SMS				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta (sec.)	424	54520	6341	
10. Ingresar al correo institucional				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta (sec.)	184	1117	332	
11. Autenticarse en el correo institucional				
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**	
Tiempo de Respuesta (sec.)	183	1253	302	



Source: own elaboration

Figure 10. Stress testing, results report

DEFINICION DE PRUEBAS			
1. Ingresar a la pagina web http://www.institutosanfrancisco.org			
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**
Tiempo de Respuesta	826	68668	8335
2. Ingresar al articulo de Vision del ISF			
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**
Tiempo de Respuesta	577	67653	9568
2. Ingresar a la galeria			
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**
Tiempo de Respuesta	418	67865	8209
3. Ingresar al modulo de Gestion			
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**
Tiempo de Respuesta (sec.)	151	11387	703
4. Autenticarse en el modulo de Gestion			
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**
Tiempo de Respuesta (sec.)	453	11096	834
5. Ingresar a un curso			
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**
Tiempo de Respuesta (sec.)	728	67746	10707
6. Consultar el horario de docentes			
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**
Tiempo de Respuesta (sec.)	509	67726	9206
8. Consultar Hoja de Vida del estudiante			
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**
Tiempo de Respuesta (sec.)	501	67799	8374
9. Ingresar al modulo de envio SMS			
Tiempos	**Minimo (ms)**	**Maximo (ms)**	**Media (ms)**
Tiempo de Respuesta (sec.)	423	68414	6928



Source: own elaboration

With this information, the capacity in terms of network elements is calculated (1):

$$N = \frac{2000KB}{44.799KB} = 44.64 \qquad (1)$$

This value is approximated to the next integer value: $N = 45$

In addition, the system is designed with a Grade of service of GoS = 99%, and with a lockout probability of the system PB = 1% = 0.01. This information is useful to determine the system traffic using Erlang B table:

For N = 45 and PB = 0.01, A is the system traffic (2):

$$A = 25.08Erlangs \qquad (2)$$

In order to know the traffic that passes through the system Ac (3), it is necessary to multiply the system traffic by system's grade of service:

$$Ac = A \times GoS = 25.08 \times 0.99 = 24.82Erlangs \qquad (3)$$

The system is designed to support moderate traffic by user (Au), namely 0.07 Erlang approximately.

U represents the number of users, and is calculated in (4):

$$U = \frac{Ac}{Au} = \frac{24.82Erlangs}{70mErlangs} = 354,57 \approx 355 \qquad (4)$$

According to the capacity of the web application designed for Instituto San Francisco to send SMS, it is possible to support up to 355

simultaneous users sending messages, which guarantees a grade of service of 99%

6. Traffic Analysis for SMS transmissions in the GRPS network

For sending SMS, the data network wherein the server (Instituto San Francisco's server) is interacting with the SMS gateway is not enough. Additionally, these messages need to pass through the mobile operator, usually a GPRS network. To this end, it is necessary to carry out the analysis of the maximum number of messages sent through the GPRS network by the web application.

If the GPRS network allows transmission speeds from 21.7 up to 171.2 kbps using CS-4 coding, boundary values are to be analyzed (minimum and maximum)

Using the minimum transmission speed of 21.4 kbps, a VTx transference speed (5) can be calculated:

$$VTx = \frac{21.4kbps \times 1byte}{8bits} = 2675bytes/s \quad (5)$$

If the data to be sent is equal to 44.799 KB, then the transmission time Ttx (6) is:

$$Ttx = \frac{44.799Kbytes \times 1s}{2675bytes} = 16.74s \quad (6)$$

For the traffic analysis, 51 messages were taken in 15-minute intervals to calculate λ, i.e. the arrival rate (7):

$$= \frac{51}{15\min} \quad (7)$$

$$\lambda = 0{,}05666 mensajes/s$$

The service rate μ (8) was calculated based on the knowledge of the value of Ts, i.e. system time:

$$\mu = \frac{1}{Ts} \quad (8)$$

$$\mu = 0{,}0597 mensajes/s$$

The utilization factor defined as ρ (9), is expressed in percentage terms in (10)

$$\rho = \frac{\lambda}{\mu} \quad (9)$$

$$\rho\% = \rho \times 100 \quad (10)$$

$$\rho = 94{,}91\%$$

With this value, it is possible to define Ls (11) as the number of expected users in the system:

$$Ls = \left| \frac{\lambda}{\lambda - \mu} \right| \quad (11)$$

$$Ls = 18{,}25 \approx 19 messages$$

Lq (12) is defined as the expected number of users in queue:

$$Lq = \frac{\lambda^2}{\mu \times (\mu - \lambda)} \quad (12)$$

$$Lq = 17.30 \approx 18 messages$$

Ws (13) is defined as the time spent using the system:

$$Ws = \frac{1}{\mu - \lambda} \quad (13)$$

$$Ws = 322.58s$$

Wq (14) is defined as the waiting time for users in the queue:

$$Wq = \frac{\lambda}{\mu \times (\mu - \lambda)} \quad (14)$$

$$Wq = 312.19s$$

The same analysis is performed for the maximum transmission value of 171.2 kbps. The results and a comparative chart can be found in Table 19.

Table 19. Traffic analysis parameters

Traffic Parameters	Minimum speed 21.4 kbps	Maximum speed 171.2 kbps
Arrival Rate (λ)	0.05666 sms/s	0.4444 sms/s
Service Rate (μ)	0.0597 sms/s	0.4776 sms/s
Utilization Factor (ρ)	94.91%	93.05%
No. of expected users in the system (Ls)	19	14
No. of expected users in queue (Lq)	18	13
Time using the system (Ws)	322.58 s	30.12 s
Waiting time for users in queue (Wq)	312.19 s	28.026 s
Probability of having 0 users in system	5.09%	6.95%
Probability of having more than 3 users in system	81.14%	74.96%
Probability of spending more than 60s in system	83.33%	13.64%
Probability of waiting more than 60s in queue	79.09%	12.69%

Source: own elaboration

The process of sending SMS consists in transporting the message through the GPRS network, using any of the GPRS service providers. Thus, the traffic analysis was performed regarding the amount of messages sent in an interval of 15 minutes, from the web application according to the section 5 of this document, and also considering the transmission speed in this network.

Using the minimum speed of transmission offered by GPRS networks, it is possible to send 51 messages in a time interval of 15 minutes, just to keep stability within the system. When this rate is exceeded, some queues arise, causing waiting times of up to 6 minutes approximately.

Using the maximum speed of transmission offered by GPRS network, it is possible to send 400 messages in the same time interval of 15 minutes. Under these conditions, the probability of waiting more than 60s in queue is reduced, namely the probability is 12.69%, compared to a probability of 79.09% obtained with the lower speed.

From the traffic analysis, it is evident that the transport through the GPRS network results in longer waiting times whenever the amount of messages grows. However, it is possible to send 50 to 400 messages maintaining a stable system with the transmission speed limits of the network. Those limits are constantly changing due external conditions such

as utilization of network, weather, signal attenuation, etc. In the same way, it is possible to have waiting times in queue in the range of 30s to 6 minutes. These waiting times are within the optimal range, considering the platform requirements and design.

7. Conclusions

At the end of the project implementation, the fulfillment of the proposed objectives was evaluated. The design and implementation of the web application tool has met the expectation of Instituto San Francisco, and has also improved the academic tracking process of the 11°grade students. This is evident also in the opinions of the academic community, which reveal that approximately 80% of the public agreed that, through the web tool, the communication process, management and tracking has improved, and thus the educational labor of the school is optimized.

According to the results of staff surveys performed at Instituto San Francisco, it is evident that the use of technology has improved the management processes. Besides, communication media such as SMS and electronic mail have proven to be effective communication media within the academic community, and they have facilitated the participation of parents in the educational processes of children.

As a result of the web application performance analysis, it can be concluded that the current dimensioning of resources is appropriate according to the needs, objectives and school expectations. The application can serve 350 concurrent users with a grade of service of 99%; it is possible that the platform may serve a larger amount of concurrent users, but this implies degradation in the quality of service.

As more functionality is added to the application, and more users are served, it will be necessary to evaluate hardware and software resource extensions, thus reducing the impact of growth on the time response offered to final users. However, current system dimensioning is planned to serve twice the number of users defined in the initial design of the system.

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