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SmartFC: Mobile Application for High School Students Supported in Flipped Classroom with Low Connectivity Conditions

Fabinton Sotelo Gomez, Lina M. Pastes Urbano, Hamil S. Terán, Mario F. Solarte, José A. Ruipérez-Valiente

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Abstract— This article presents the SmartFC mobile application, an application aimed at students which allows the implementation of the flipped classroom model compatible with the use of ICT (Information and Communications Technologies) even in conditions of low or no connectivity. This proposal not only allows the visualization of open educational resources but also capturing the record of the effort made by students during the development of an academic activity, which represents a significant advantage over the majority of applications used to deliver thematic content. Besides, this application allows two-way communication between students and teachers.

Index Terms— Flipped classroom, high school, Technology Platforms.

I. INTRODUCTION

Technology is currently advancing in a dizzying pace and it is impacting all social spheres [1]; education is one of the areas where the current technological ecosystem got a considerable impact [2,3]; proof of this, is the way in which information and communication technologies (ICT) have been implemented; which have made available tools for educators and students that made it possible to improve the implementation of teaching and learning models [4]. In the same way that society changes, educational models also seek to reinvent themselves and adapt to the current trends, relying on technological tools that are available to them today [5,6,2]. One of the models that have been implemented the most is "Flipped Classroom" which is defined as a pedagogical approach in which direct instruction moves to the individual learning space, and the resulting group space is transformed into an environment of dynamic and interactive learning where the educator guides the students to apply concepts and get creatively involved in the subject [7,8,9]. In this model, readings are used and more recently with the support of ICT videos and multimedia elements [10,11], so that students study them individually, before class. Studies have shown that the flipped classroom model has been shown to be more effective compared to traditional teaching models and has had a positive impact on students' academic results [12,13,14,8]. Although the definition of the flipped classroom is not subject to the use of technology [15,16], many authors see this as an opportunity to improve the learning process. The literature shows the existence of different tools that can be used to support this model; however, there is no evidence that these applications or tools have been used in environments where internet connectivity is limited or deficient. Based on the above, this article proposes a mobile application to support students in the learning process based on the flipped classroom model, even in low connectivity conditions. Next, the main characteristics of the flipped classroom model are highlighted; the architecture implemented in the application and finally, a brief description of the case study is made where the application proposed here is used.

II. FLIPPED CLASSROOM MODEL

The flipped classroom is a teaching model whose main objective is that the student can assume an active role during the learning process, for reversing the processes and roles that occur in traditional teaching models [9,18] as for example teaching the lecture supported in the multimedia tools out of the classroom. In the same way, the class time is used to answer questions, carry out practices, open discussion forums and reinforce the learning through interactive methods of collaborative work [17,19]. proposed in Bloom's taxonomy. It proposes that lower-order cognitive processes, which in traditional models are linked to environments within the classroom, can be extrapolated outside of it, which means that students can study the theoretical concepts by themselves through different tools that the teacher makes available for them, such as videos or podcasts recorded by the teacher or other people. Also the class time is used to answer questions related to the material provided and delve into the topics [20,21,22]. A series of studies have been found in the literature [21,23,13,14], which show that, when applying the flipped classroom model, better results were obtained in the evaluations compared to the traditional class courses, in addition to improving motivation and promoting self-directed and self-

[1] Fabinton Sotelo Gomez is with the Department of Telematics at the Universidad del Cauca and Fundación Universitaria de Popayan, Popayan, Colombia (e-mail: fabinton.sotelo@unicauca.edu.co).
Lina M. Pastes Urbano is with the Department of Telematics at the University of Cauca, Popayan, Colombia (e-mail:linapastes@unicauca.edu.co).
H. Teran is with the University of Cauca, Popayan, Colombia (email: hamil@unicauca.edu.co).
Mario F. Solarte is with the Department of Telematics at the University of Cauca, Popayan, Colombia (e-mail: msolarte@unicauca.edu.co).
José A. Ruipérez-Valiente is with the Department of Information and Communications Engineering at the University of Murcia, Murcia, Spain (e-mail: jruiperez@um.es).
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regulated learning in students [8].

This model clearly defines three learning moments. The first is "before class", which supports lower-order cognitive processes such as:

- Remember: It consists of recognizing, remembering, listing, and recalling relevant information from long term memory.
- Understand: It is the ability to interpret, exemplify or construct meaning from educational material, whether they are readings, videos, or explanations

The second moment is "during class", in which the student is inside the classroom consolidating knowledge with the teacher's guidance. During this time, support is given in higher-order cognitive processes which are:

- Apply: It consists of the use or application of a learned process to solve different problems.
- Analyze: It is to differentiate, organize or decompose knowledge into its parts and think about how these are related to its overall structure.
- Evaluate: It consists of verification and criticism. It allows to compare and discriminate between ideas and choose based on reasoned arguments.
- Create: It Involves gathering knowledge to carry out creative tasks, to generate, plan and produce something new.

Finally, the last moment is "after class" in which the student does the review of tasks and the enhancement of themes individually.

In order to find what kind of technological tools have been used to implement this model within the context of High school education. A bibliographic review was carried out, through a systematic search in the online databases of SCOPUS and WOS (web of science) from 1999 to September 30, 2019 [9] with the search string “(Flipped classroom) AND (Inverted learning)”. From this search, 61 articles were obtained that showed the implementation of the flipped classroom model in secondary education [45]. This study showed that most flipped classroom implementations only make use of technological resources for the sections before class, and the most used technological resource in the studies analyzed are videos/conferences [24,25,26,27,28,29]. Regarding the use of tools for the management of academic content, it could be observed that all the tools found were applied in contexts where the internet service was available, and mostly, these platforms, were only used to deliver the content to students [30,31,32,31,33,34]. In consequence, it can be a problem, since there is no way to verify the actions, participation, or behavior of students outside the classroom [28]. From this literary review, it was identified that the application should not only accompany the student during all the moments of their learning process but also capture measures that allow determining their behavior before class, in addition to operating in low connectivity environments [45].

III. FEATURES OF THE APPLICATION

Taking into account the above, and to support the guidelines of the flipped classroom model, the telematics application is based on the management of activities. They are defined as the set of instructions and elements that allow one to achieve an academic objective and cover all the levels of the Bloom pyramid. So, It is divided into three moments presented below:

- Before class: It Supports lower-order cognitive processes and it consists of a series of prompts for students and a set of OER elements (Open Educational Resources) for students for consulting. In addition there is a test that allows corroborating the completion of the first moment of the activity by the student.
- During class: At this time, support is given to higher-order cognitive processes, for this it is proposed to make use of a workshop prepared by the teacher that allows students to consolidate knowledge and reach the last levels of the Bloom pyramid. Finally, during this time an evaluation is carried out to verify the work carried out.
- After class: During this time the student has access to the activities so that they can perform reinforcement exercises.

In addition and for supporting the ideas above, the application must collect the browsing events that the student performs while he is active in the application. It determines a series of metrics that allows us to see the student behavior and check the completion of tasks at the moment "before class".. Finally, the application must work in environments with low connectivity, in such a way that it allows to implement the model even in areas where there is no internet access, and not take this service as a determining aspect that prevents the implementation of the model in marginalized populations. The following sections show the process carried out to define the metrics that the telematics application must generate; and the architecture that enables it to function in low-connectivity and connected environments.

IV. METRIC DELIMITATION

One of the main aspects to take into account for the development of the application, is the capture of metrics, [28] in order to determine what measurements should be captured, a literary review was carried out that made it possible to determine the set of metrics necessary to capture the effort made by students outside the classroom. The platforms analyzed were Moodle [35,36,37,38,39], Blackboard [39, 40], Chamilo [38.41], KAcademy [42] and finally Coursera [43]. From this review, it was possible to identify a set of 79 metrics, to which a statistical analysis process was applied that consisted of eliminating the metrics that are not part of the flipped classroom model, such as those related to certifications; then the similar metrics founds in each of the tools were filtered.

This process allowed reducing this set of metrics to a total of 30.

Figure 1 details the filtering process where the "x" axis represents the abbreviated name of the metric (table I) and the "y" axis represents the number of coincidences or similarities of each metric on the platforms analyzed. In this way, it was possible to determine that the set of metrics found allows observing the behavior of students outside the classroom and identifying important aspects such as the type of connection that the student has, the number of times they access the content, and if it is capable of responding to a questionnaire of the subject seen. Table I describes the 30 metrics generated by the mobile application. The first thirteen metrics are related to the process that the student carries within the application at different times. these could provide the student or the teacher with a record of their interaction with an activity. The fourteen and fifteen metrics reflect the type of connectivity that The student possesses within the platform. Them, metrics from the sixteenth to the twenty-seventh are related to the activities that the students develop on the platform, and the last metric is considered as the grade according to the activities that the student developed on the platform.

V. MODULAR ARCHITECTURE OF THE MOBILE APPLICATION

To support the flipped classroom model, it was decided to design a mobile application, integrated with a teaching activity management system. It can allow teachers to create activities based on the flipped classroom model and later being able to work with students. The purpose is that the application can consume the activities that the teacher generates, allowing in this way the deployment of the activity and the collection of metrics. The architecture proposed in figure 2 not only allows to support the flipped classroom model but also works in low connectivity environments, through the following three layers:

A. Network layer

In the first layer, there is a server hosted in the cloud through the infrastructure as a service (IaaS) model, which is connected to a global database and a central repository. Within the database, the data of each of the schools are housed, as well as a bank of activities and in the repository, there are all the OER elements available for use by students with an internet connection.

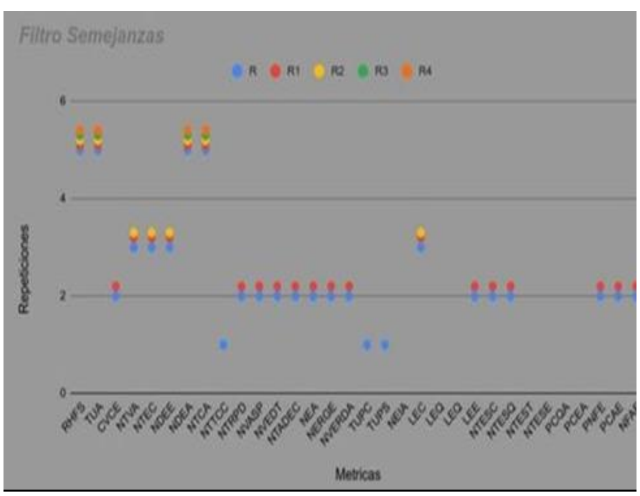

Fig. 1. Metric filtering.

TABLE I
METRICS CAPTURED BY THE APPLICATION

#	Metric name	Abbreviation
1	Date and time stamp that enters the system	RHFS
2	Usage time in an activity	TUA
3	Display check of a student's content description	CVCE
4	Total number of students interacting withthe activity	NTVA
5	Number of times the student accesses the content	NTEC
6	The number of doubts sent by a student.	NDEE
7	The number of doubts sent about an activity.	NDEA
8	Test note on the content of the activity.	NTCA
9	Number of times a teacher answers questions	NTRPD
10	The number of times you access the platform's visualization services.	NVASP
11	Number of times the student downloads a workshop	NVEDT
12	Activity evaluation grades	NTADEC
13	Type of connectivity in which the student uses the application	NEA
14	Quiz verification "check-in" activity by student	NERGE
15	Number of students who started the activity	NVERDA
16	Number of evaluations carried out duringthe degree by the student	TUPC
17	Assessment verification check on the activity per student.	TUPS
18	List of students who saw and did not the content	LEC
19	List of students who saw and did not seethe quiz	LEQ
20	List of students who saw the workshop and not the ones who did not.	LEQ
21	List of students who saw and did not seethe evaluation	LEE
22	Number of students who viewed the content and the ones who did not	NTESC
23	Number of students who took the quiz and the students who did not	NTESQ
24	Number of students who saw the workshop and the ones who did not	NTEST
25	Number of students who did and did not take the assessment	NTESE
26	The average grade for an activity quiz	PCQA
27	Average rating of the evaluation in an activity	PCEA
28	The average final grade of activity for all students	PNFE
29	Percentage of completion of all activitiesper student.	PCAE
30	The average final grade of activity for all students	NFAE

B. Local layer

In the second layer a local network is located, which is in each of the schools, this network is also composed of a server, from where the information of the telematic application directed to the students is managed. This server is in turn connected to a database and a repository of resources. In this case, the database contains the information of each school; while in the repository a subset of REA elements is located which are stored in it from the synchronization with the upper layer located in the cloud through the HTTP protocol, in addition to the REA elements created by each school.

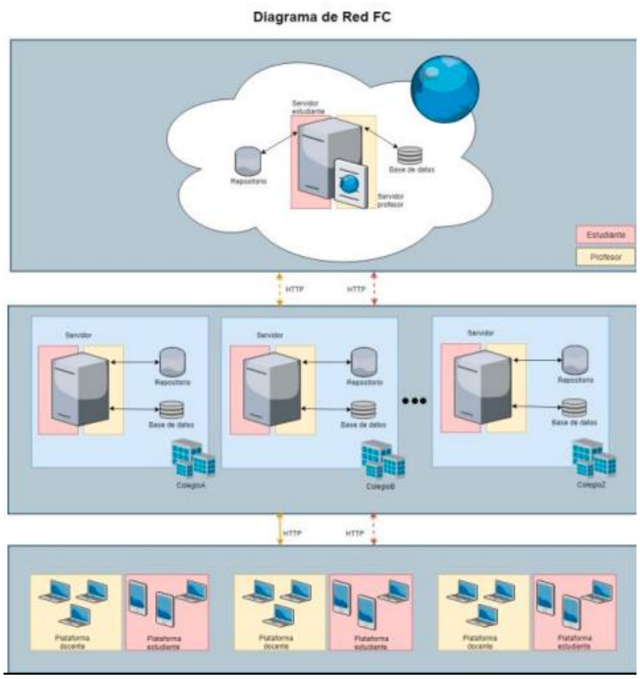

Fig. 2. Network architecture.

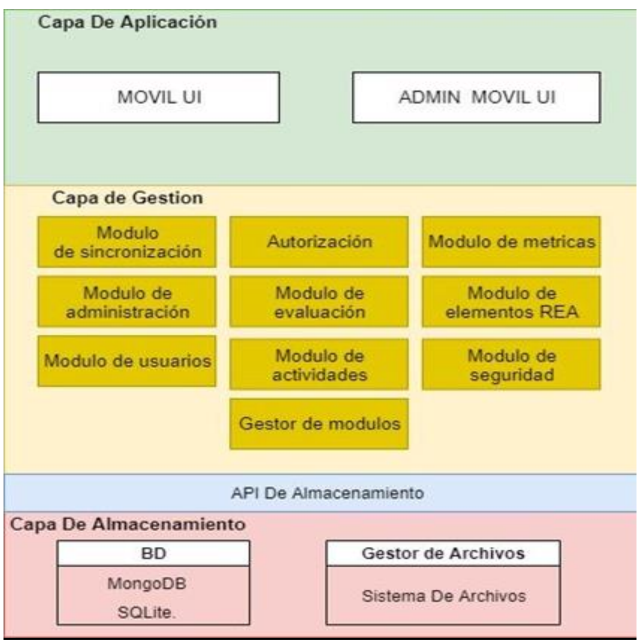

Fig. 3. Layer model.

C. *Client layer*

In this layer are the end devices on which the telematics application of a mobile nature runs; which allows students to download each of the activities and store them locally, in such a way that students can perform them even if they do not have internet, the data collected by the application will be synchronized with the servers of the upper layers as soon as the device has internet or is in the coverage area of the local network.

The mobile application is capable of supporting the three moments established in the model guidelines, in addition to operating in low connectivity environments, this application must capture the events that will allow generating the metrics later; For this purpose, a software architecture with 3 layers was built to support the requirements posed by the flipped classroom model (Figure 3).

A. *Application layer*

This is the layer that the user sees; where the graphical interface that the application will present resides. In this layer, a mobile application is located that allows students to interact with the activities assigned by the teachers.

B. *Management layer*

In this layer, it is all the logic of the application, where the user requests are received and the corresponding results are presented. To solve the requirements of the model, the following modules are used:

- Synchronization Module: It allows the application to synchronize with the servers of the local or network layer, depending on the case, aside from identifying the connection mode (local, or network).
- Administration module: It allows you to manage and administer the created accounts, administer users and reset passwords.
- Module Manager: It allows the communication between internal modules and manages communication between adjacent layers.
- Authorization Module: This allows the user to manage the necessary permissions and authorizations for the application to work efficiently.
- Evaluation Module: It allows the deployment of evaluations and the storage of responses within the application.
- Activities module: This allows the user to interact and store the content of the activities locally on the device.
- Metrics module: This module allows the user to capture and store the events necessary to generate the metrics of the effort made by the students.
- REA Elements Module: It allows the visualization of REA content according to user preferences.
- Security Module: It is in charge of the encryption processes and data protection.
- Users Module: This allows you to create student accounts, modify data and reset passwords.

C. *Storage layer*

In this layer, we find the database managers, who are responsible for receiving requests from the management layer and returning the corresponding data.

The previous architecture is capable of supporting the flipped classroom model, even in low connectivity conditions. It also allows identifying some aspects about what the student does during the moment he/she is not in the classroom. For consequence, the metrics collector module is one of the most important things in this proposal. Nextly, important points of its implementation are described.

II. METRIC MODULE

The main contribution of this proposal is the capacity of the application to carry out the metric collection process, for this, the system requires the capture and storage of events, which are focused on analyzing the participation of the student in the platform [44] among the events that need to be captured and stored are: the click event, date and time of registration, date and time of starting the session, date and time of closing session. This leaves a click and event log, called a flow, which is associated with a particular student. To do this, the application builds a log event, which groups the events with a user identifier (ID). From the storage of the events and the synchronization that the application makes with the server, a data mining process will be carried out, which allows generating the metrics.

III. APPLICATION PROTOTYPE

The SmarFC application was developed based on the XP development methodology. The methodology allowed defining the roles to be assumed by each one of the team members. A set of 4 iterations were established for the development of the application with a time of 3 weeks for each one. The solution obtained consists of a mobile application for Android devices developed in React-native. Then, the functionalities of the application are detailed. The SmartFC application allows the user (Student) to create a personal and unique account (figure 4). When you enter the application you will be able to find the assigned activities by each one of the teachers of your grade divided by the different subjects (figure 5); so, each activity is divided into 3 parts (figure 6) called within the application as practice at home, practice in class and take the exam. In practice at home, the activities of the moment are developed before class, while to complete the moment in class, the following two parts are developed: first the practice in class and second, the activity where there is a workshop to develop in the company of the teacher, and the final evaluation, that allows to evaluate the subject. In addition, the student can access all the REA content, stored in the repositories, either locally or on the global server; the student can also communicate the doubts he has on the subject and synchronize them with the server to later receive feedback from the teacher (figure 7). Another important aspect is that the application allows the student to view her progress in each activity; as well as the results of the evaluations and quizzes (figure 8).

IV. CASE ESTUDY

To test the collection of metrics, it was decided to carry out a case study at the Santa Catalina Labore school in the municipality of Bolívar Cauca in Colombia, with the aim of answering the following research question: How to verify the collection of metrics of the effort made by the student out of the classroom? To respond to the previous question, a sample of 31 tenth grade students was taken, who were given an introduction to the flipped classroom methodology and the management of the “SmartFC" application, then, they were subsequently asked to interact with the activity called “Use of the rule of 3 to calculate percentage ”, later they were asked to perform the synchronization of the captured events with the local server installed on laptop Asus brand Intel i5 processor at 2.7 GHz, RAM 8Gb and 480 SSD in the school. In figure 9 you can see the number of registers stored in the database, which corresponds to 115 records, which allows verifying that the collection metrics were carried out successfully. Besides this, during the case study, two surveys were implemented one before starting the interaction with the application, which consisted of doing a survey to find out socio-cultural aspects from the surveyed population; and another one after the end of the interaction with the application to determine the degree of acceptance of the technology.

As a result of this process, it was observed that in a96.7% of students, they own a smartphone for their personal use; Besides, they highlighted in their majority that the quality of the internet in their school is deficient, and the 32.2% answered that they do not have an internet connection at home; what validates the hypothesis that the application should work in connected environments and in which there is low connectivity so that the internet is not an exclusion factor in implementing academics models that make use of the ICTs. On the other hand, the results of the technology acceptance survey were highly positive, where 87% of the students affirm that they intend to continue making use of the application (figure 10, figure 11).

The results showed to be positive, it was possible to verify the collection of metrics in a real way in an environment with low connectivity conditions. The students considered the use of this application to be advantageous to improve the learning processes that they currently carry, and a degree of intention to use of 87.1% was obtained, which does not lead to the conclusion that the tool is highly accepted by the students, due to its ease of use and its perceived usefulness.

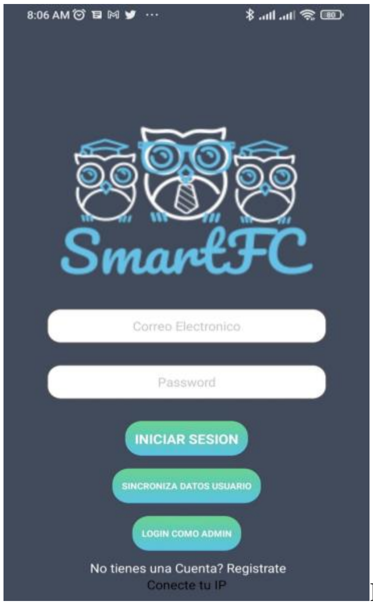

Fig. 4. Login view.

Fig. 5. View of subjects and activities.

Fig. 6. learning moment's view.

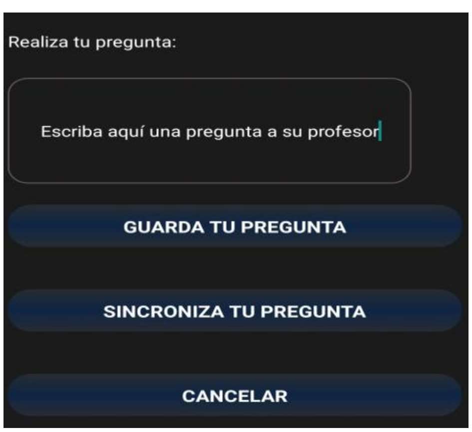

Fig. 7. Register doubts

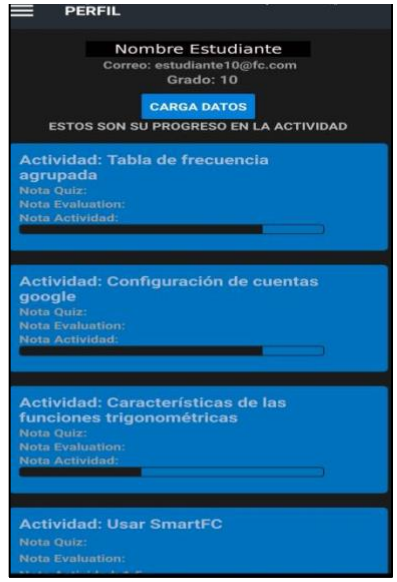

Fig. 8. Student profile

V. CONCLUSIONS AND FUTURE WORK

It is necessary to emphasize the importance that it has for the learning process of the students of schools and colleges, that the way in which they learn is updated and reinvented according to the needs and trends that are currently presented. Based on this, the flipped classroom molding allows incorporating the use of ICT in the teaching and learning process, as well as allowing students to form a more critical and proactive vision during learning. One of the most important parts of the flipped classroom model, which until now has not been applied consistently; is following what the student does outside the classroom, therefore the metric collection system plays an important role when creating an application. that supports students during the learning process; Another aspect to highlight is that, most of the investigations in which flipped classroom and ICT are applied, have been carried out in environments where the internet connection is guaranteed, in the other hand for the populations where this service has not ensured, its the implementation was a difficult type of model, which was confirmed, when implementing the case study where a third of the population did not have access to the internet in their homes or when they had a poor connection in their schools. To continue with the research, it is necessary to develop a broader case study that allows verifying the impact of the use of the telematics application on the academic achievements of students, who adopt the flipped classroom model. In addition, the development of the application, allows improving the experience of students within the application.

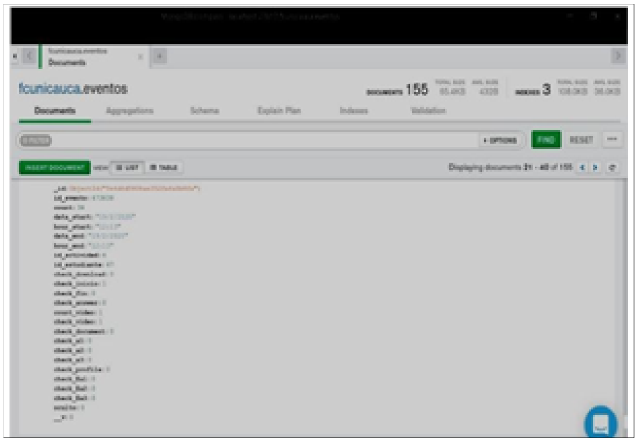

Fig. 9. Metric record

Fig. 10. Intent to use Perceived utility

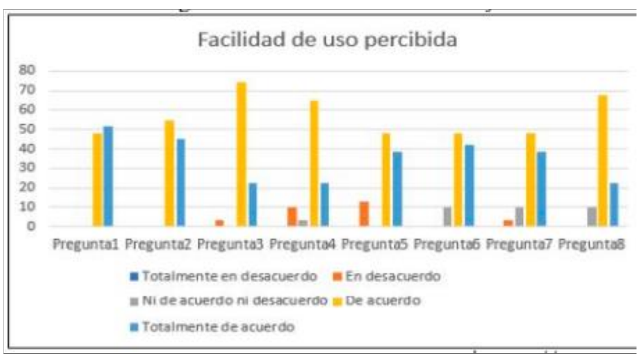

Fig. 11. Intent to use Perceived ease of use

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Lina M. Pastes Urbano. Electronic and Telecommunications Engineering Student (University of Cauca-Colombia). She is a collaborating member of the research seedbed Líbero of the FUP (Fundación Universitaria de Popayán); His main research interests, including virtual educational environments, flipped classroom, blended learning, learning analysis, and computer science

Hamil S. Terán. Electronic and Telecommunications Engineering Student (University of Cauca-Colombia), currently he is a global member of the Internet Society, also member of the Spanish chapter of the Internet Society (ISOC-ES) and collaborating member of the chapter IEEE AESS Unicauca (University of Cauca). His research interests include virtual educational environments, flipped classroom, blended learning, learning analysis, and computer science.

Fabinton Sotelo Gomez. Received his master's degree in telematic engineering from the Universidad del Cauca since 2013 and a systems engineer from the Universidad Nacional Abierta & Distancia (UNAD), He belongs to the IMS research group of the Fundación Universitaria de Popayán and a doctoral candidate in the telematic engineering department of the Universidad del Cauca. His research interests focus on massive online courses, e-learning, blended learning, and flipped classroom.

Mario F. Solarte. Received his PhD in telematic engineering from University of Cauca since 2019. MSc in Telematic Engineering since 2009. Specialist in formulation and evaluation of social development projects, from the Iberoamerican University Corporation in 2000 and electronics and telecommunications engineer from the University of Cauca. He currently works as a researcher and professor in the telematic engineering department of the University of Cauca and collaborates in various research projects. His research interests focus on eLearning, Massive Online Courses, Learning Styles and Digital Education Contents.

José A. Ruipérez-Valiente (Senior Member, IEEE) received the B.Eng. degree in telecommunications from the Universidad Católica de San Antonio de Murcia and the M.Eng. degree in telecommunications and the M.Sc. and Ph.D. degrees in telematics from the Universidad Carlos III of Madrid while conducting research with the Institute IMDEA Networks in the area of learning analytics and educational data mining. He was a Post-Doctoral Associate with MIT. He has received more than 20 academic/research awards and fellowships. He has published more than 90 scientific publications in high impact venues and participated in over 18 funded projects. He currently holds the prestigious Spanish Fellowship Juan de la Cierva with the University of Murcia.