PBLMaestro: A Virtual Learning Environment for the Implementation of Problem-Based Learning Approach in Computer Education

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***Abstract*—Teaching Computer has led to the design of an educational model that is increasingly making use of market practices linked to business corporations. Within this scenario, a practical and dynamic learning system is being fostered that allows simulations to be carried out in real contexts through problem resolution. Based on constructivist theories, PBL (Problem-Based Learning) is a teaching method that is focused on the students and its main characteristic is that it uses real-world problems to create the learning content and teach the skills required for their solution. However, the adoption of this approach is not an easy task, since it is accompanied by abrupt changes in the traditional paradigm of education, which require changes in the attitudes of the actors involved. In addition, the planning and monitoring of the PBL, involve complex activities that are difficult to manage, especially with regard to determining the quality and compliance of the processes used for problem resolution. Additionally, the Computer Science courses require working on projects provided by real clients, within a dynamic and iterative development process. This strengthens the need to introduce strategies and technologies to support the implementation and management of the method and, enable its effectiveness to be monitored In addition, it provides continuous feedback,, and assesses the results generated from the evaluation of the solutions produced during the teaching-learning process. Thus, it is essential to adopt strategies that allow a better management of teaching practice, improved learning by the students and a means of validating the clients involved. From this perspective, this paper presents a virtual teaching and learning environment, called PBLMaestro, which has been designed to support the workflow of a methodology for the implementation of PBL in teaching Computer Science, called xPBL. With the aid of xPBL, it is possible to perform the management of courses using the dynamics of a cycle and series of stages to allow a better control of management processes, by linking real problems to well-defined educational goals. In the case of teacher planning, we were used elements described in xPBL methodology, aligned with educational goals defined from the Bloom Revised Taxonomy. With regard to student tracking, we used the authentic assessment model and mechanisms of Learning Analytics. Gamification strategies were included to increase engagement, retention and motivation, and push notification messages were displayed in a mobile application the PBLMaestro was validated by means of application the environment in the context of the discipline "Network Design" of Computer Science Course, and the results are analyzed in this study. In addition, semi-structured interviews were conducted with the teachers and there was a high degree of satisfaction among the tutors, students and customers who used the service, with regard to the usability and consistency of the proposed environment as well as with its improvements and changes. Although the environment was improved in the area of computer science, it is possible that it can provide support to the STEM context with some customizations.**

Keywords— Problem-Based Learning; PBLMaestro; Virtual Learning Environment; Computer Science; Gamification.

I. Introduction

The effectiveness of adopting the PBL method [1, 2] depends on the management of the activities involved in the teaching and learning process, especially in the stages of planning and monitoring. In adopting an approach that is predominantly process-oriented [3],there is a real need to ensure an alignment between these stages. The alignment of the theory to the problem, as well as the dependence of educational goals and consistent forms of assessments are challenges faced by process management in this approach. Moreover, the process of teaching and learning in PBL requires an evaluation of activities that are based on principles and reflect their own teaching practice, while seeking to maintain the quality of the process and hence its effectiveness. These activities, might entail establishing clear educational objectives that are suited to the context, and supported by classificatory schemes such as Bloom's Taxonomy [4] and the definition of assessment strategies that can underpin clearly defined objectives.

As a teaching student-centered approach, the method enables students to carry out problem solving in an active and collaborative way, by encouraging multi-learning styles and allowing interpersonal factors that can also be developed and/or improved. In view of this,, there is a need to design an evaluation that is appropriate, in all these respects, and which can be implemented in the context of the computer science courses. PBL provides students with problems of complexity similar to those in the real world, and these must be evaluated from different perspectives, as happens in real situations, and even include the client, who is the stakeholder which demand the business requirements. With regard to this, one appropriate strategy for employing the principles of PBL is to design an authentic assessment model [5], [6] that can provide an evaluation of students, using criteria such as: content, process, results, performance and client satisfaction. By ensuring that learning is focused on real problems, this can occur in a flexible, unpredictable and dynamic way and there are good prospects of situations and unexpected questions arising during the resolution process. In this approach, the teacher's role in PBL is to give assistance and guidance to the students so that the learning process can be continuously monitored, and information about any problems detected can be given through constant feedback. By observing this scenario, we could see that during the application of the method, the teacher was faced with many variables and had to handle a wide range of situations . In general, it was clear that the management of teaching practices through this approach was a difficult task and was sometimes carried out in a superficial way due to the lack of mechanisms and tools that could give the necessary support for the planning, implementation, monitoring of the PBL. In this context management for educational processes, the xPBL methodology [7], which is based on PBL, includes its own methods and management strategies and consists of features that have been mapped in accordance with PBL principles. One benefit of xPBL, is that the adoption of strategies related to the management of teaching and learning processes can be employed for planning their implementation [7]. The flexibility and dynamics of the methodology can be employed to ensure the reliability and quality of the principles underlying it.

Within this context, this paper supports the potential value of virtual learning environments as powerful aids to education, by improving communication and interaction between people and, especially, the management of activities and processes. In this scenario, this work proposes the PBLMaestro tool that employs the xPBL methodology, by providing mechanisms to plan, manage, monitor and document the workflow of the methodology. The PBLMaestro provides an environment that offers solutions to the problems and difficulties that affect the adoption and use of the PBL method: i) difficulties in effective management method; ii) difficulties with the subjective aspect of the method, the lack of well-defined process flows, facilitating the problem proposition as well as the development of the solution; iii) difficulty to follow up the progress of the process of developing solutions through learning indicators; iv) lack of implementation of well-defined evaluation parameters; v) difficulty in evaluating the group and individual aspects; vi) difficulty of keeping students engaged and motivated throughout the process. Environments were created for the teacher, student and client to enable the planned interactions to occur. Gamification mechanisms [8] and Learning Analytics [9] were also provided. In PBLMaestro, a) the teacher can, (in several environments), carry out the management and monitoring of all the stages defined for the methodology; b) the student will have access to modules for reporting the decomposed solutions to problems, and be able to track their progress in the course based on defined criteria for authentic assessment; c) the client, in turn, can interact, monitor, assess and address the needs arising from the problems. Testing was performed for the validation of the tools during the execution of discipline "Networks Design" of Computer Science Course. In addition, an interview with teachers and students was conducted to understand their level of usability.

II. xPBL Methodology

On the basis of the principles of PBL, a methodology was devised by the N.E.X.T. (Innovative Educational Technology in eXperience) group that defined the methodology that combined management methods and tools through PBL applications in the area of Computer Science [7]. This decision reflected the fact that it was essential for PBL to be strongly oriented processes. This group has conducted research in this field since 2007 and other results are described in [12, 13, 14 and 15]. The xPBL proposes an extension of the features proposed by Barrios [10], (the advocate of PBL), and includes two principles, which are as follows: the learning is collaborative and multidirectional and PBL is supported by planning processes and continuous monitoring. As a way of ensuring the quality of the processes, the xPBL requires the teaching and learning process to be based on the PDCA cycle of Deming [11], as well as the application of the 5W2H technique to define the guidelines for the methodology . The elements of xPBL include the problem, environment, content, human capital and process and can be defined as a mapping of PBL principles. Table I shows how the mapping was performed from the principles of PBL to the five elements of xPBL.

TABLE I. Elements of xPBL and PBL Principles

Mapping PBL principles and elements of xPBL	
PBL Principles	***xPBL Elements***
1. All learning activities are anchored on a task or a problem;	Problem
2. The learner should feel he/she owns the problem, and is responsible for his/her own learning;	
3. The problem should be real;	
6. The learning environment should stimulate and at the same time challenge the learner´s reasoning;	
4. The task and the learning environment should reflect the reality of the professional market;	Environment
5. The learner needs to own the process used so as to work out the solution to the problem;	Content
7. The learner should be encouraged to test his/her ideas against alternative views and contexts;	
9. The learning is collaborative and multidirectional;	Human Capital
8. The learner should have the opportunity and support to reflect on the content learned and the learning process;.	Process
10. PBL is supported by planning processes and continuous monitoring.	

Looking at Table I it is clear that the xPBL Problem element is the most closely related to the principles of PBL (1, 2, 3 and 6). In short, this element strengthens the form of learning in PBL which regards the problems as a central feature of this process. The student should feel "owner" of the problem, for this, it should describe it together with the customer, through interviews and meetings. As well as the problem element, the environmental element mapped to Principle 4, highlights the need for a learning environment that reflects the current conditions in the labor market. A good example of this principle is the simulation of a Software Factory environment where students take on the roles and responsibilities needed for finding the technological solutions demanded by real clients. Since it is a methodology aimed at students, the principles of 5 and 9 express the idea of responsibility and show the students' attitudes to the learning process in PBL which occur in a collaborative and multi-shaped way. Principle 7 reinforces the need for the teacher to analyze the proposed solutions before their effective implementation. And even if learning is predominantly practical, the "content element" strengthens the need to link the problems to the fundamental principles and concepts. Finally, the "element processes" when mapped to Principle 10 involve the idea of monitoring and conducting ongoing assessments throughout the process with a focus on finding out learning difficulties and providing guidance through targeted feedback. By observing the principles and their relationships, it is clear that there is a serious challenge when it comes to their management, implementation and documentation throughout the teaching and learning process that this approach entails and, hence, a need to include tools that can assist in this process as an interesting and timely strategy.

A. Authentic Assessment

In line with these activities,, it is essential to plan a means of combining the educational objectives and the evaluation itself. Establishing a fixed relationship between the elements is an educational objective which forms the basis for the construction of the evaluations, in the same way that the evaluations are carried out to determine if these objectives have been attained. In short, an educational objective is a statement that involves from an expected change in learning, or skills that the student can acquire while solving a problem. A goal should be described clearly and objectively, and this article will examine goals that are concerned with changes in learning supported by the classificatory scheme called Bloom's Taxonomy [4] as well as arranging statements, and classifying them in accordance with different levels of dimensions. Together with this, and the evaluation of strategies, xPBL recommends adopting an evaluation model for an authentic assessment since this appears to be based on the philosophy of PBL and include different perspectives in this process. Originally defined by [5], this underlines the importance of applying knowledge to stimulate thinking and encouraging students to conduct a critical analysis to solve real problems, and finding different ways of solving them. The Authentic Assessment model aligned with xPBL comprises five dimensions, that are: content, process, result, performance and client satisfaction. Overall, authentic assessment is intended to ensure a fair assessment of the content that is drawn on to solve the problem. The 'content' refers to perceptions of the teacher with regard to the knowledge that the students have acquired in the course. The process evaluates how students performed the planning and decomposition in the stages involved for the solution of the problem. The dimension of the result is characterized by the quality of the delivery, i.e. the artifacts produced as a solution to the problem. The performance in turn is linked to the performance of the student when solving the problems by checking the skills and attitudes required for this process. The forms of assessment linked to performance relate to assessments of 180 and 360 degrees, commonly known as self-assessment and peer reviews. The goal of self-assessment is to make the students reflect on their perceptions during the learning process, especially when faced with difficulties . The students have to define strategies to improve their learning and this self-assessment becomes indispensable. The peer review is a way of tracking the relationship of the team while they are solving problems and thus intervene in situations ? common in traditional teaching practices. Finally, customer satisfaction dimension involves an assessment from the customer's perspective as this is who demand the requirements and approves the changes in the solution developed by the team. Understanding the features and applicability of these dimensions is essential for the development of the tool module that implements the management of the evaluation procedures.

III. Implementation Process of xPBL Methodology

Before setting out the details of the PBLMaestro tool, it is necessary to carry out the details of the procedural flow that were designed from the xPBL methodology. The generation of this process was important to outline the flow of activities implemented in the tool. Figure 1 shows the adapted PBL process which was originally proposed by Barrows [10] and is based on the xPBL methodology. For the purposes of this work, we set out four key stages: i) description of the problem; ii) solution proposed by generation of solutions hypotheses; iii) finding the solution to the problem and iv) authentic assessment. It should be noted that the actors were involved in each stage of the process, and an evaluation of the description of the problem and proposed solution were included.

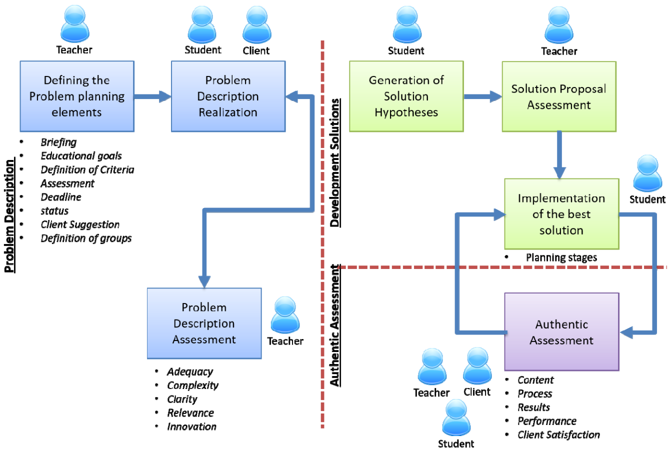

Fig. 1. Workflow of the PBL Methodology

Table II shows the relationship between the proposed model and the xPBL principles.

TABLE II. RELATIONSHIP OF THE XPBL PRINCIPLES WITH THE PROCESS THAT IS IMPLEMENTED

Principles	***Implementation***
1. All learning activities are anchored on a task or a problem;	Principle 1 is working on the core of the model, since the problem is the central feature of the approach. The whole work cycle is centred on a problem.
2. The learner should feel he/she owns the problem, and is responsible for his/her own learning;	Through a description of the problem stage, the learner becomes the “owner” of the problem, since the problem is described to meet the client's needs.
3. The problem should be real;	With the client is included in the process, the working problem is embedded in some real market context.
6. The learning environment should stimulate and at the same time challenge the learner´s reasoning;	The problem is complex enough to make it possible to achieve the proposed educational objectives, and hence, the teacher will evaluate the description stage of the proposed problem.
4. The task and the learning environment should reflect the reality of the professional market;	This principle will be adopted if the teacher establishes an environment in the classroom.
5. The learner needs to own the process used so as to work out the solution to the problem;	The learner is the driving-force behind the process of resolving the problem, planning and finding the proposed solution. During this process, the group decomposes the delivery solutions .
7. The learner should be encouraged to test his/her ideas against alternative views and contexts;	Within the defined process, the solutions are always analyzed by the teacher before being implemented by the students.
9. The learning is collaborative and multidirectional;	The model offers stakeholders an environment with collaborative strategies among participants.
8. The learner should have the opportunity and support to reflect on the content learned and the learning process;.	This is achieved through the constant feedback given by teachers, students and clients throughout the process. In addition, as in the case of gamification strategies, it can have a learning idea of progress.
10. PBL is supported by planning processes and continuous monitoring.	The process involves finding a solution and through continuous feedback (Principle 10) guides the students to attaining their educational objectives and as a result the contents are achieved. This feedback is supplied by the actors involved, in the context of the dimensions of authentic assessment.

Figure 2 shows the possible states in the workflow for the resolution of the problem, from the planning stage, through the time of description, to the solution, development and evaluation of the problem. This view has been implemented in the proposed tool and enables stakeholders to have a clear view of the stages that have already been undertaken and those still missing in the specific context of a problem.

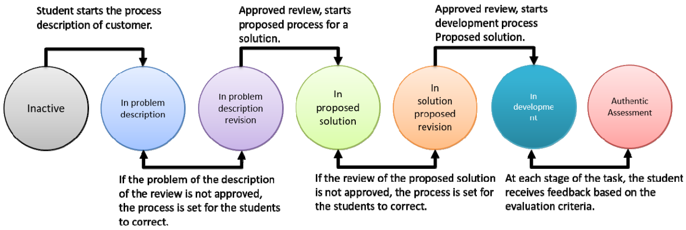

Fig. 2. Possible states in the problem-solving process

As a supplement to the explanation of Figure 2, Table III shows the possible states and their descriptions.

TABLE III. STATES AND DESCRIPTIONS

State	**Descriptions**
Inactive	The problem has not yet started.
In problem description	The problem was set by the teacher for the students to carry out the description to help the client .
In reviewing the description of the problem	The teacher assesses whether the description is in accordance with the defined criteria.
In the proposed solution	The problem was set by the teacher for students to carry out the proposed solutions to help the client .
In revision of the proposed solution	The teacher evaluates whether the proposed solution has been found in accordance with the defined criteria.
In development	After t the set problem has been solved, the “flow” enters the development stage. At this stage, the students will decompose the solution in stages by performing the delivery planning .
Authentic Assessment	In this stage, the submitted delivery of the artifacts for solving the problem will be assessed by the teacher, student and client, using the dimensions of authentic assessment and its criteria. This assessment is applied to the delivery of each artifact produced.

Figure 3 shows a timeline which temporally allocates the sequence of actions that occur during the description process, solution proposal, development and evaluation of the problem. In the context of this example of a problem, the term for the completion of all stages is 30 days. The first time period is the description of the problem; in this time the student will describe the problem situation on the basis of the requirements stated by the client for this. The group used a description questionnaire model that was defined by the teacher during the planning stage. When the description process has been completed, the teacher evaluates the quality of the produced description of the problem by pre-defined criteria. If it is approved, the proposed solution phase begins; this is when students will make suggestions for the proposed issue and as a result, the solution chosen by the group will also be assessed by the teacher. If any of these steps is not approved, the teams can use the feedback to improve the information and request a further review. In the event of the submitted proposed solution being approved, it can begin to be developed by the teams. During the development process, the solution can be decomposed into several stages (E1, E2, E3). At the end of each stage, the teams submit their “delivery” for evaluation and the teacher, student and client obtain a score based on the criteria defined for the dimensions of authentic assessment and may supply feedback to the team. This cycle is maintained until the delivery of the final stage. It should be emphasized that during the process the client evaluates the deliveries and also supplies feedback based on the criteria for the evaluative dimension of client satisfaction. The students also make a self-assessment and assessment of their peers for each delivery and make use of the performance evaluation dimension.

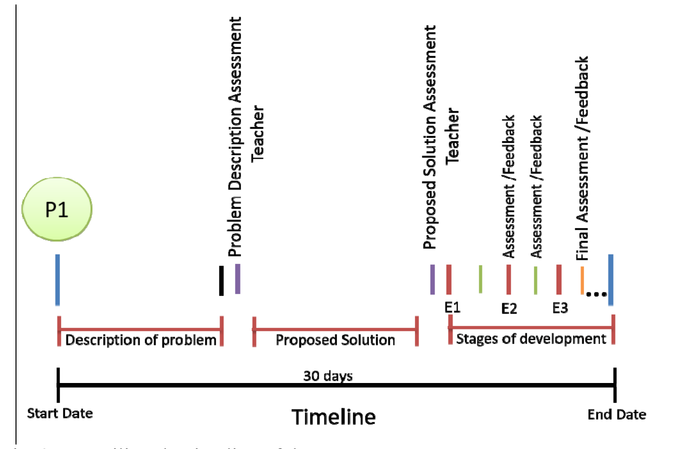

Fig. 3. Detailing the timeline of the process x PBL

IV. Related Work

In this section, we discuss some platforms, which more resemble the tool presented in this work. Initially it performed an analysis of these, which were listed deficiencies, and its main characteristics, based on comparison parameters that are considered important in the context of this work. The works [26, 27, 28, 29, 30, 31] propose environments have been developed for the application of PBL approach. The State of the Art Lifting and analysis of these works were important for the design of this proposal. After this process, it was observed that there are some gifts requirements PBLMaestro that the analyzed environments do not implement, and we consider essential for the implementation and management of the method, from the top, we can mention: the lack of a procedural flow well defined, which guide the actors involved in the process proposed by the method; the lack of customer participation, important actor who demand the needs to the problem; the lack of well-defined evaluation parameters; the lack of association of educational objectives to the problem; the lack of mechanisms that produce greater commitment and motivation on the actors involved; the lack of learning indicators accompanying tools.

V. PBLMaestro Environment

An architectural specification is essential to analyze and describe the properties of the system. It enables components, mechanisms of interaction and their properties to be identified. The development of a service for the implementation of teaching and learning processes, based on the xPBL methodology requires an architecture that enables the components to be integrated. This is designed to meet specific requirements such as the following: the management of processes associated with problems, collaboration strategies, mechanisms communication, gamification, and learning analytics, among others. In addition, a software architecture that aims to support this type of service, requires a strategy for the description, organization, development and evaluation of issues, including mechanisms for their generation, execution, control and monitoring .

A. *Technologies Used*

The PBL Maestro tool was designed by means of the Java language as back-end technology, and the architectural Model-View-Controller (MVC) standard [17]. Services and components have been developed that are based on this architecture, and where the facade is the entry point to the business layer and where services are added. The Java Persistence API (JPA) was used in the layer model and Hibernate was used to keep the application independent of the Database Management System (MySQL), while the setting was performed by annotation. The purpose of the DAO pattern (Data Access Object) that is used in the architecture is to separate the code that deals with the persistence of the business logic code in the database. The AngularJS [18] was used as an open-source JavaScript framework, maintained by Google, which helps single-page applications run. The library reads the HTML that contains special tags and then executes the policy where its tag belongs, thus making the link between the vision and model, represented by common JavaScript variables. The number of these JavaScript variables can be set manually or by a JSON resource. Figure 4 shows the system architecture which was designed from the above-mentioned specifications and requirements.

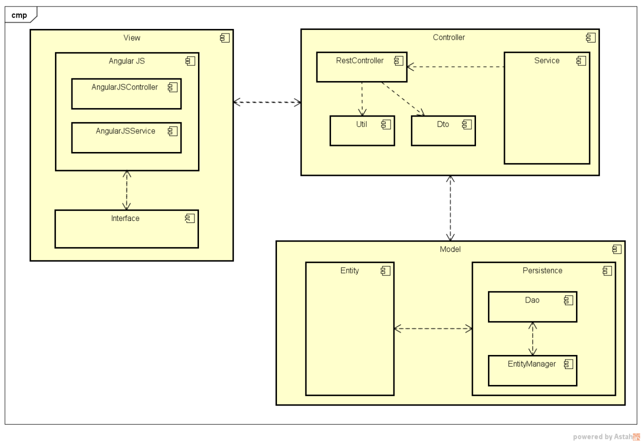

Fig. 4. PBLMaestro Software Architecture

B. *Core Modules Tool*

This section provides descriptions and interfaces of the main modules of PBLMaestro.

1) The xPBL Management Module: the main module tool that is responsible for the implementation of management mechanisms for planning management, execution, control, development and evaluation of the problems and solutions. This is designed to provide three main environments (teacher, student and client) that provide stakeholders with an experience based on their responsibilities.

2) Gamification Module: The gamification requires the use of elements that are traditionally found in games such as narrative, feedback systems, rewards systems, cooperation, competition, objectives and clear rules, progress, levels, fun, interaction, etc. [8]. From this perspective, we developed a gamification area with the aim of displaying the group's status within the course through a playful view of the process. This involved implementing a spatial setting, where problems are represented by planets. For this part of PBLMaestro, the programming language C# and the Unity platform were used [23].

3) Learning Analytics Module: The Learning Analytics module [9] involves developing a software architecture model that allows the storage and use of educational historical data by students, which are generated by interaction with the PBLMaestro. This architecture means that by applying Learning Analytics techniques, and focusing on the diagnosis of a learning situation, it was possible to collect, measure, analyze and examine data on the behavior of students; thus, teachers and educational managers can make decisions about how to improve and adjust the teaching-learning process. At first some related work of theirs was investigated: Gismo [19] SNAPPVIS [20] geekie GAMES [21]. This stage was important for understanding the state- of -the -art with regard to the way analytics learning tools are being developed. The second stage was to select Charting JavaScript libraries to build graphs for data visualization. Chart.JS [22] was chosen for this task.

4) Communication and Messaging: Responsible for providing synchronous and asynchronous communication mechanisms. With regard to this, attention should be drawn to the implementation of the push notification mechanism which is designed to enable participants to be informed of the continuation of the procedural flow at every stage, through messages displayed on the web and mobile version of PBLMaestro. This notification mechanism uses an architecture based on microservices and runs parallel to the main architecture described in Section A. Spring-websocket-chat API was used for the generation of notifications and JPA and Spring Data was used for the peristence of the data.

C. Main Interfaces

This section outlines some of the PBL Maestro interfaces.

1) Teacher Environment: The area of the teacher is where there are most management resources, and there is a set of mechanisms and interfaces for this purpose.

a) Problem Management: Figure 5 shows the Problem Management interface, where the following can be defined: the briefing and goals that educationally linked to the problem, the dimensions of evaluation, forms of description and solutions, groups of students and clients, and finally, the deadlines.

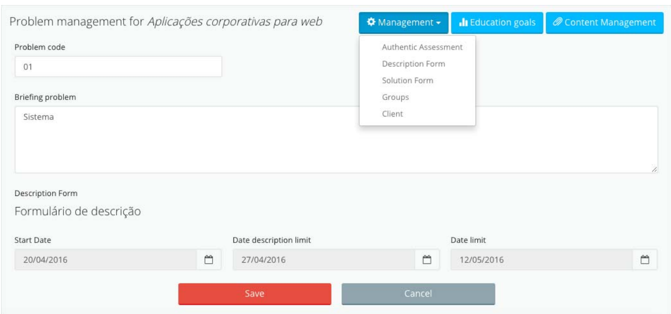

Fig. 5. Problem Management Area

b) Authentic Assessment: Figure 6 represents the teacher's view of the authentic assessment for a specific group. It can be seen that there is a radar chart with the performance for the five dimensions.

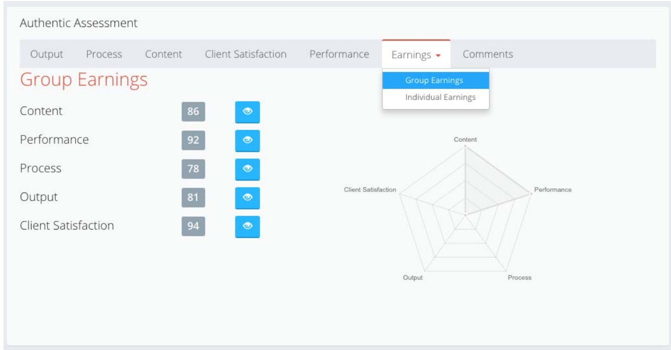

Fig. 6. A View of Authentic Assessment

2) Student Environment: Figure 7 provides a view of the student area where the wizard with the process definition it can be seen with the following stages: problem description, proposed solution and solution development. In the "development tab" shows the the activities submitted by a group of students who were decomposed in the sphere of solution development planning. It should be noted that it is the group of students who are responsible for the planning of deliveries, and this action is evaluated by the teacher in the context of authentic assessment perspective, called "process".

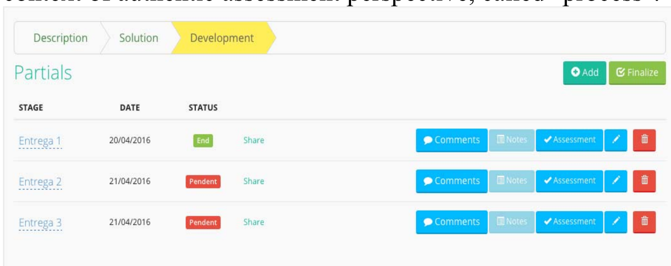

Fig. 7. Students viewing area for finding a solution

a) Gamification Environment: As shown in Figure 8, the dynamic works as follows: when the method of solving a problem by the group is approved by the teacher, the spacecraft "traveling" from this planet to another, gives the idea of progress. In the game environment, badges and a ranking system were made available as an incentive for greater motivation and engagement.

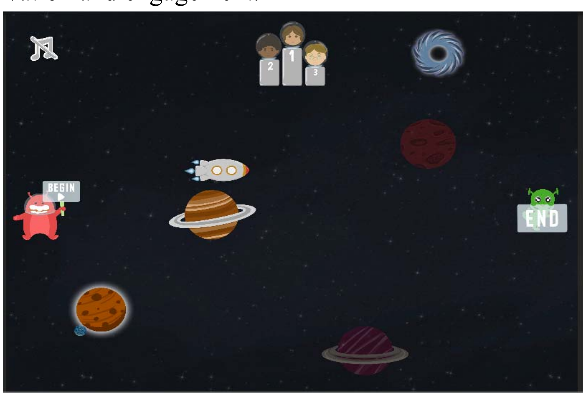

Fig. 8. The Gamification Environment

3) Client Environment: In the xPBL methodology, the client is an essential factor in the process. An environment has been created to make client interaction possible (see Figure 9), where this actor can view the partial deliveries of the solution, assessment and carry out feedback via text or files.

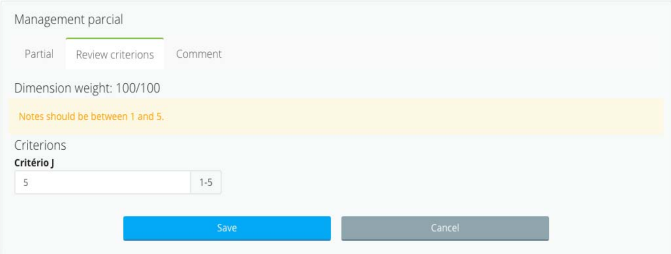

Fig. 9. Client Area

VI. Results

The tests were conducted during the discipline “Network Design” in Computer Science Course. The aim of this course is to carry out a computer networking project for a particular organization. The dynamic groups interacted with real customers so that by employing a top-down methodology [24], it was possible to define the scope of the problem and then find a solution. All the interaction between the teachers and students took place in the classroom with the help of PBLMaestro. In the sections that follow, further information is provided on the scenario chosen, to establish a relationship with xPBL elements. It should be noted that one of the advantages of using PBLMaestro, is the possibility of analyzing the data at any point in the process without the need to set milestones for later tabulation. However, to make this possible, the results in this study were defined in terms of four (4) marks (kickoff, SR1, SR2 and SR3).

A. Environment

The groups conducted interviews with clients in the business environment. To ensure an environment that is conducive for real practice, the institution where the course was run also provided a laboratory similar to what is found in real environments with equipment and sufficient infrastructure for finding a solution .

B. Problem

In the first stage, the students are initially given information about the top-down methodology cycle. This approach is widely used in creating problem situations combined with the current network design. In a second stage, the students began the description stage of the problem with the client to understand the context and the demands for each case. The development of the network project was carried out in the environment required by the client. In this stage, students worked on the setting of three IT companies.

C. Human Capital

With regard to the human capital element, the class consists of 20 students, divided into 4 groups of 5. The criteria used to construct the groups were practical experience in the area, prior knowledge of the top-down methodology and a professional profile. In the process, the participants were the teacher, tutor and students. The tutor had to continuously support the learning of the students. The tutor with a technical profile worked t most of the skills required for the course and the aims of the teacher when carrying out the activities. In addition to the technical area,, the process was aligned with the xPBL methodology. One of the students played a leading role and this participant was responsible for carrying out deliveries for the group through the tool.

D. Content

The course was conducted by the teacher with the assistance of a technical tutor, who employed the Top Down methodology proposed by the author Priscilla Oppenheimer as a benchmark[24]. In addition, there was a lecture on the PBL and dynamics of problem-solving which adopted the approach of the Delisle model [2]. The course was run in 3 modules: 1st module made use of the Top Down methodology and aimed to ensure the understanding of the key concepts underlying the project development area, and especially the stages of its cycle; 2nd. module conducted an analysis of the network requirements ; and 3rd. module addressed the stages of logical design, physical design and budgeting.

E. Assessment Process

The evaluation model implemented in this case study was structured as follows: the first objective was to assess the description of the problem, to ensure quality was maintained at this stage. In achieving this, the teacher evaluated the proposal in accordance with the following criteria: suitability, complexity, clarity, relevance and innovation, and determining the specific settings for the needs of each group. After the description of the problem had been approved, the students explored hypotheses and proposed a solution that was only assessed by the teacher, after this stage, the groups began to look for a solution. In the developmental stage, the groups followed the stages for finding the solution. These were evaluated with the aid of the authentic assessment model, using the five dimensions: Content, Process, Results, Performance and Client Satisfaction. In the process dimension, the teams were evaluated on the basis of five questions : "What is the objective of your project?"; "What's your plan?"; "What has been done so far?"; "What are the strengths?"; and "What are the points that need improvement?". As evaluation criteria, the following dimensions were defined: clarity of presentation; mastery of the presentation; completeness when considering the five questions and understanding of planning. Each indicator can be given a score on a scale of five values, as follows: "1 - Insufficient; 2 - Regular; 3 - Good; 4 – Very Good; 5 - Excellent". The results for the first module, achieved scores with concentrated higher values between 6 and 7, unlike the results of the second and third modules where there was a concentration of between 8-9 and 9-10, respectively. With regard to the dimension of the results (Figure 10), this was focused on the analysis of the content of deliveries of the stages of the proposed solution and presentations in follow-up meetings. These analyses were conducted on the basis of the following criteria: project overview; planning activities; the performance of activities; strengths and areas for improvement.

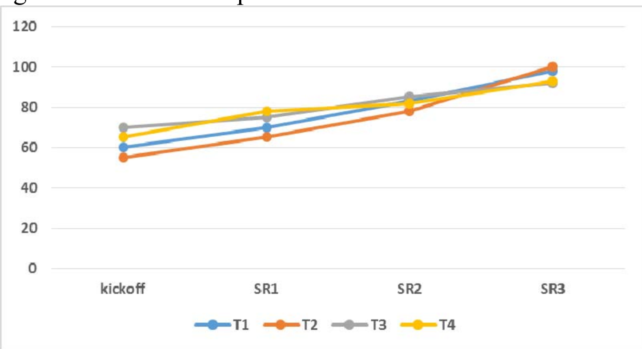

Fig. 10. Dimension of the graphics output area

In the performance dimension, eight competencies were evaluated: self-initiative, commitment, collaboration, innovation, communication, learning, planning and analysis. Owing to the subjectivity of the analysis, this approach used a scale of five values, with the following variables : expectations not met, partially met; met in a satisfactory way ; fully met and exceeded expectations. The assessment was applied in the form of a self-evaluation and a normal evaluation, where each member of a team was evaluated by their peers anonymously. On the basis of these data it was possible to detect conflicts and provide feedback in real time. Finally, the evaluation of client satisfaction followed the following criteria based on the following: performance in interviews; understanding of the problems; clarity of presentation; quality of the proposed solutions and the level of planning. This assessment used the same scale of values dimensions: process and outcome. Figure 11 shows the graph for the results of the teams in this dimension; it can be seen that there is a concern on the part of the teams with regard to their relationship with the client. This mainly concerned, meeting their needs, since the teams were generally evaluated in a positive way.

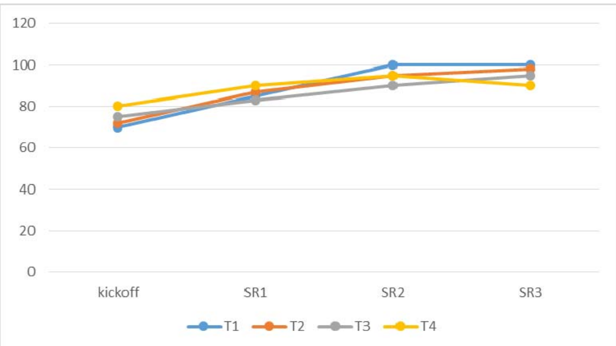

Fig. 11. Dimension Graphics for Client Satisfaction

F. Validation of Usability

In validating questions of inherent usability, an interview with 20 students, 4 teachers and 2 clients, was carried out using the format called the System Usability Scale, proposed by John Brooke [25], which is composed of 10 questions. Figure 12 shows the source of this information.

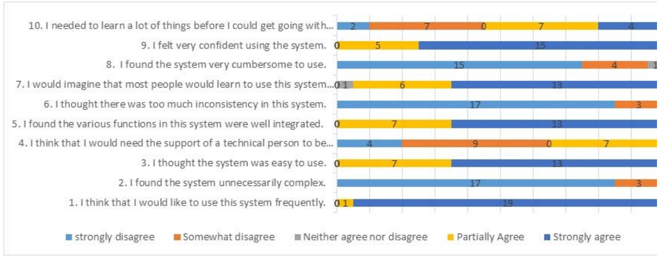

Fig. 12. Graph with the results of Interviews

VII. Conclusion

The N.E.X.T group has been working with the PBL method in computer science education for more than eight years. A constant concern of the group was to find a systematized approach for the application of the method and thus improve the way this is managed through management techniques. The group applied the xPBL methodology systematically, as observed in the work [12], however without using a tool that was specifically designed to support the flow. Still on the [12] work, the management of the process was done using various applications that did not communicate, and neither were developed for this purpose, in addition, there was a difficulty in compile of the educational student data, damaging the assertiveness of feedbacks from the teacher; in PBLMaestro tool, this problem was solved using Learning Analytics mechanisms, with the monitoring of student performance happening in real time. With the implementation of strategies of gamification, it was possible to observe a greater degree of engagement and motivation among the students, and this affected the quality of the delivered solutions. As a result of maturity acquired in xPBL, it was possible to define the requirements and the process for the implementation of the PBLMaestro. The tool proved to be suitable for xPBL processes and was evaluated and used by students, teachers and clients, with positive results on regarding the difficulties for adoption of PBL presented in the Introduction (section 1). It was also confirmed that, the tool had a good evaluation from the point of view of usability and consistency. By using the five dimensions of authentic assessment, it was possible to evaluate the performance of students in different aspects of the course. The assessments based on size "content" allowed the concepts and fundamentals that students had more difficulty could be identified and treated. The use of dimensions "process", "result" and "cliente satisfaction" allowed the identification of groups with greater maturity in the planning process and management solutions, and that they were meeting the requirements proposed by the customer. The evaluation of "performance" allowed an individual look with regard to engagement, participation and dedication in the group. In future work, we intend to apply the tool to other courses, increase the number of reports generated by the Learning Analytics strategies and define other possibilities for gamification to the system. Studies are being conducted that make it possible to converge with other methodologies such as Design Thinking.

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