A PBL Approach to Process Management Applied to Software Engineering Education

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Abstract—Given the demand in the area of Software Engineering for solutions that actually contribute to modern organizations, the search for qualified professionals who have considerable practical experience has been growing day-by-day. Set against this background is the learning process of traditional teaching, in which the Student is largely a mere recipient of information, including concepts and theoretical foundations, and is seldom given practice in problem solving. Therefore with a view to minimizing this problem, teaching and learning methods such as the Problem Based Learning (PBL) have emerged in higher education as an approach to foster changes in teaching and learning processes, which are aligned to the new requirements of the labor market and redefine the roles of those involved in educational processes. To evaluate these processes, a case study on skills training to teach Usability Testing is discussed, and important results presented that show the applicability of the proposed approach for teaching Software Engineering.

PBL; Process Management; Software Engineering; Education.

I. INTRODUCTION

The continuous growing on the informatics market implicates in a bigger search for qualified professionals who are able to analyse and solve complex and various problems. Even though, it’s easily noted how their education ends up being damaged by the use of traditional learning methods, in which the learning process enhances the theoretical learning in solving problems. It’s also worth noticing that when trained in such a way, there is no relevant contribution to the development of skills to be considered in the professional condition. The lack of practical learning, where realistic practices are hold through simulated scenarios based on the current job market, hinders the Students from assuring an experience in dealing with complex situations associated to the interpersonal relationships required to this process.

Before this context, it comes to be relevant to consider the need for embracing training with different guideline approaches, intending to minimize the vantage in technology’s market, as well as providing quality training to the professionals in the area. In order to attend to this need, new teaching methods, like the Problem-based learning have been introduced in higher education as an alternative in contrast with the traditional education.

Problem-based learning (PBL) [1] is compatible with the job market, once it promotes essentially a functional and practical learning by the use of problems which are similar to the ones found in the market. It’s considered necessary to emphasize the alignment of the practices to the theoretical knowledge in an integrated way, what allows that non-technical abilities to be also developed.

Focusing on the Student, this concept has as inherent process the use of problems to initiate and motivate learning concepts and the promotion of necessary skills and decisions to come to a solution [2]. Even being best known in medicine, it has been applied in various areas, as in software engineering, where the results are considerably satisfying.

The benefits of the embracement and the changes in the learning process in PBL are evident. The redefinition of the roles in this process assigns Students, who are active agents, the responsibility of building their own knowledge through the collaborative learning, whereas the teacher takes the responsibility to guide the Student through the building process as a facilitator. However, many challenges have been faced in order to get effective results by its endorsement. In particular, the process management stands, because PBL is strongly directed to process [3], when considered that the term “process” is defined as being a “set of behaviours or activities performed by people or machines to achieve one or more objectives”. Accordingly, the PBL process defines itself as a set of activities that aim its effectiveness by the preservation of the principles to achieve the requested objectives.

In this context, this paper proposes a PBL approach in education modeled on BPMN – Business Process Modeling Notation, but considering the method elements proposed in Santos [4] by the problems definition, practical learning environment, flexible content, human resources role, and the process of authentic evaluation.

II. THE XPBL METHODOLOGY

The essence of PBL in being directed to process determines the need of a process that supports defined steps, as the planning, implementing, monitoring and continuous evaluation as a way to guarantee the theory’s alignment (concepts) to the problem (practice) during the whole learning process. These steps refer to PDCA (Plan, Do, Check and Act)
cycle, defined by Deming. As tool also applies to educational processes, the cycle promotes them through the management of the organization and proper execution of the activities of steps aimed at continuous improvement. The PDCA cycle was proposed as reference elements of the methodology xPBL.

In this article, emphasis will be given to the stages of planning and execution. The process, focused on the PBL approach to Software Engineering education, had as foundation the relation of the five principles of PBL elements proposed by Santos [4]:

1. Real problems: the problems must be real, asked by real clients, of reasonable complexity and relevant to the field and educational goals;
2. Real environment: the practical learning environment based on software industries promotes a better comprehension of the process by the Students, specially in its functions and responsibilities, activities and strategies to accomplish the clients satisfaction and the quality in the products;
3. Human resources involved: the value of each person involved contributes to the process growth in general, according to his or hers experience, education and formation, where the Students get supported by each other and also tutors, monitors and even the client during the learning process;
4. Content: with the purpose of promoting a holistic view of the Software Engineering area, the resumes must be according to SWEBOK (Software Engineering Body of Knowledge);
5. Assessment processes: based on the authentic assessment strategy defined by Herington and Herington [5], the Students are involved in learning environments in which the activities are turned to the application of their knowledge, stimulating their ideas and critical vision and the implantation of different ways to solve them;

As a way to check these processes, the article presents the results of an experience in applying the elements of a case study proposed to Software Engineering studies, emphasizing Software tests accentuating usability.

III. APPLYING THE XPBL METHODOLOGY IN REAL CASES

This section has as main objective to present some successful real cases, verifying the veracity of the PBL method. The Software Residency described in [4] was planned to form software engineers in the BADA platform for mobile devices, or by simplification “BADA Residence”, used the Software Factories model as a practical learning environment, having the SIDI Samsung Institute as real client of this project and CESAR as educational institution [6]. The Software Residency in Telecoms market – performed in a partnership between CESAR (www.cesar.org.br) the institution of technological innovation and Datacom Brazil (www.datacom.com.br) – had the objective of creating specialized professionals in a short period of time, so Datacom could hire, as it needed professionals with the required skills for new project [7].

In the Software Quality area, the Training in Software Tests (PCTS) was performed, aiming for offering the Students the proficiency and the dissemination of the technical knowledge on the Software tests area, using the PBL methodology [3]. It was implemented by the Software Productivity Lab (LabsPS) of National Institute of Science and Technology (INES) in the Informatics Center of Federal University of Pernambuco (Cin-UFPE), with the collaboration of partners from the innovation institute C.E.S.A.R. (Recife Center of Studies and Advanced Systems) and of the software industry of Pernambuco, Brazil [8].

IV. PBL IN PROCESSES

In computer science there is a difficulty in having qualified professionals in Informational technology area, as, for example, software engineers. Some education methods try to solve this challenge, as PBL, that offers the Students a way to get the knowledge and developing skills and attitudes expected from a professional. The process based in xPBL methodology was created to assure the correct application of the PBL.

This section describes the formation structure of the Planning and execution processes based in xPBL methodology, referring to the five elements of the PBL approach in education: Real Problems, Real Environment, Human Resources, Content, and Evaluation Processes. Was seen the need to create one more element to join the elements of the methodology, the PBL Plan. The PBL Plan contains the steps of each activity, as a schedule, human resources involved and application place. It's clearly defined and aims at the entire process to be applied.

The process is composed by three splits that indicate the active people in the process, like the Client, the Coordinator and the Teacher/Tutor. In each split are the subdivisions.

A. Real Problem

The use of problems is a main tool on the PBL methodology, where it must be defined a specific problem based on real context and complexity. After defining the problem, the new learning activities start, that need to be connected to concrete facts, always searching for the reality in context. The definition process of the problem may begin from two situations, as shown in Fig. 1:

- Client defines the problem to be solved through a paper with its description and then pass it to the coordinator, when he or she will analyse the description and verify if the problem fits the PBL concepts so it can be passed to the teacher;
- The definition of the problem comes from the coordinator, so the same sends the actual problem to the Teacher through a paper with its description. The problem may have as objective to form test engineering, for example.
After defined the problem, the Teacher sets the educational goals, as shown in Fig. 2. Educational goals are defined objectives to determine in a most effective way which content level is wanted to achieve through a previously taught concept [7], are learning expectations over the Student.

**B. Real Environment**

In appropriate environment gives the Students a better structure to find the resolution of the problem (Fig. 3). This sub process is a coordinators responsibility since the definition of the local infrastructure and the necessary hardware, networks and softwares that the Students will use until the place and applications to be used are defined.

**C. Human Resources**

It’s a key part of the planning process, because the value of each person involved contributes to the process growth as all, according to their experience, education and formation. The people involved are the Students, Teachers, Tutors and the Coordinator. Next, we will verify each one’s role.

- **Student**: composes the team, and are responsible for performing the activities, having active role inside the PBL methodology;
- **Teacher**: responsible for teaching and preparing the subjects content, making the learning easier;
- **Tutor/Technician**: specialist on the PBL methodology and also responsible for supporting the Students, helping with the activities projections and assuring the application of the method;
- **Coordinator**: responsible for the demand of the problem, leading the methodology implementation, executing monitoring activities and validating results. and;
- **Client**: responsible for defining the actual problem.

According to the lack of professionals, Teacher and Tutor can be just one person (Teacher/Tutor) in this Process, provided they have the technical capability to both roles, as shown in Fig. 4.

Coordinator is the responsible for the definition of the teachers, tutors and the selective process itself, while the Teacher/Tutor is responsible for participating of the selection process and defining the teams, assigning roles and responsibilities for each one.
D. Content

It involves definitions of the subjects to be taught, defining their content related to the problems context and also defining the support material, like tests, exercises, etc. These definitions must be made by the responsible Teacher, according to the Students need for the problem resolution (Fig. 5).

E. Assessment Processes

The evaluation must have a diagnostic function, checking the educational situation of the Students to propose improvements by the Teacher. In the proposed evaluation process, the Teacher/Tutor verifies if the educational goals were accomplished through mapping. The Coordinator defines the evaluation modalities, as well as its processes and the grading criteria (Fig. 6).

F. PBL Plan

The actualization of the PBL plan is of a huge importance because a starting point is necessary so that the whole process may be applied in a clear and objective way (Fig. 7). Containing the step by step of each previously quoted element, as, for example, who will be involved inside the human resources and which are the defined contents.

After accomplished the entire planning part, we move to the execution process, which is the second part of the process, where we apply what has been planned. After the Client describes the problem, the Coordinator receives the same and checks if it is necessary to divide the problem. If so, it divides and after, sent to the Teacher/Tutor.

The Teacher/Tutor is responsible for receiving the problem from the Coordinator and pass it to the Student, who analyses it and searches for solutions. If the Student finds troubles in the resolution, he or she may ask the Teacher/Tutor for help. After the questions are taken, the Student finishes the task by delivering the artefact to the Teacher/Tutor. When receiving the artefact made by the Student the Teacher/Tutor makes the following evaluations; process, performance, content and artefact. The Teacher/Tutor must also verify for fractionated problems and make the same evaluation to the remaining
problems. For last but not least, the Teacher/Tutor checks if the problem which was described by the Client was solved and sends it to the Coordinator. If the problem was not solved, the Teacher/Tutor requests the Student to correct it.

When the artifact is delivered to the Coordinator, he or she passes it to the Client, who will evaluate the work. If the artifact is according to what was requested, the Client gives a positive feedback of the final product (artifact), which is passed back to the Coordinator, then Teacher/Tutor and finally, to the Student. If the artifact is not according to the requested, the Client asks the corrector for a check, who will sent it to the Teacher/Tutor, who will pass to the Student, starting a new cycle of execution until the problem is solved.

V. APPLYING THE PBL PROCESS

Savery & Duffy establishes eight basic PBL principles and emphasizes the need for supporting all learning activities and processes in a real problem inside a real context of an environment similar to the working place.

Before that, we chose to apply the process into a Software Test training emphasizing usability, in order to form qualified professionals inside the software quality field for the job market, in a similar environment to the working place, using the LMS Amadeus system to verify its usage, attached to the value to the system.

In many universities the term 'Software Test” is neglected, so the Students end their courses with little or none knowledge about this subject.

Software Test is the execution process of a product to determine if it has achieved its specifications and worked fine to the environment for which it was projected. The test does not depend on the development process for each stage (analysis / project / development). The objective is to expose flaws in a product, so that they can be fixed before the final delivery, achieving liability and making the software quality better [8].

The training was performed in CIN- Informatics Center in Federal University of Pernambuco in association with CiTi-Integrated Center of Informational Technology. Next, the description of the application of the process through the six elements:

A. Real Problems

The real Client defined the real problem “Our educational institution needs to adopt a management system of an easy use to support the learning processes of the technical courses offered. However, the communities Students rarely access the Internet, in addition to not having an ease in dealing with the computer itself. They told me about “Amadeus”, but we really need to analyse this possibility!”. After validated the problem by the Coordinator, who verified that the problem was in the context and was consistent, it was sent to the Teacher, and he defined the educational goals. The educational goals were based by Blooms taxonomy, where know, understand, apply, analyse, synthesize and judge the following educational goals:

- Basic Concepts of PBL;
- TestLink tool;
- Amadeus tool;
- Basic Concepts of Usability;
- Basic Concepts of Software Test.

B. Environment

CiN- Informatics Center of UFPEs lab was selected, with one computer per Student with access to LMS Amadeus and TI TestLink (tool and management of test-cases simulating a software test industry.

C. Human Resources

The industry was structured with professionals with abilities compatible to the established objectives of the training, and interacted with the Students teams. So, each Student got continuous support from the Teacher/tutor. The client also frequently interacted with the teams, making the understanding of the problem easier to be solved. The teams division was performed in a homogeneous way, avoiding one to be weaker than other.

D. Content:

The following disciplines were selected according to the Students needs: Introduction to PBL, Amadeus tool presentation, Software test, TestLink tool and Usage Test.

E. Evaluation Process

The evaluation was based on the authentic evaluation by Herrington and Herrington [5], where the five elements the PBL approaches were evaluated based on the process xPBL.

1. Content: formative and summative evaluations were made to check the Students knowledge, evaluations those, made before and after each provided discipline. The table below shows the global evaluation of the Students referring to groups A and B. The result was announced at the end of the course, following the summative evaluation approach. The training used had three distinct activities of evaluation, such as:

a. Exercise 1 was carried out for writing test cases as a whole;
b. Exercise 2 was to write test cases for usability;
c. The interaction was applied according to the students behaved performing the
above activities and were interacted with the rest of the group. The criteria used for writing the test cases for both test cases in general and for the test cases for usability were the clarity, correctness and completeness. Was used at 5-point scale of values in the evaluation: "Excellent" (5) "Very good" (4) "Good" (3) "Satisfactory" (2) "Low" (1). The average content (Table I) was calculated by summing the values assigned to each question, and divided by the number of questions.

<table>
<thead>
<tr>
<th>Team</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.47</td>
</tr>
<tr>
<td>B</td>
<td>3.13</td>
</tr>
</tbody>
</table>

2. **Process:** The items to be analysed were projects presentation, deadlines and goals planned versus deadlines and goals accomplished, strong visions and improvement points. Due to the subjectivity of the analysis, a range of 0 to 10 points values were used, then the average taken. Notice that in the Table II, the grades were very tight, where the Students attended well in the process.

<table>
<thead>
<tr>
<th>Team</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8.8</td>
</tr>
<tr>
<td>B</td>
<td>8.6</td>
</tr>
</tbody>
</table>

3. **Results:** The items to be analysed were understanding was applied that the teams had about Software tests, usability and PBL methodology, verification and validation of the artefacts, as well as the improvement in softwares usage. Due to the subjectivity of the analysis, a range of 0 to 10 points values were used, then the average taken. And about grades, we can see that team A was superior to team B (Table III), even though it must be considered that this group had lost two of its members.

<table>
<thead>
<tr>
<th>Team</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>9.7</td>
</tr>
<tr>
<td>B</td>
<td>9.2</td>
</tr>
</tbody>
</table>

4. **Performance:** A self-evaluation was held and also a constructive evaluation between the Students themselves [9]. It covered the self initiative, the capacity of learning, the collaboration, the communication and the focus on results. Was used at 5-point scale of values in the evaluation: "Excellent" (5) "Very good" (4) "Good" (3) "Satisfactory" (2) "Low" (1). The average content was calculated by summing the values assigned to each question, and divided by the number of questions. Notice that in the Table IV the team B has a good performance, even being in a number disadvantage.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Team A</th>
<th>Team B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self initiative</td>
<td>3.38</td>
<td>3.6</td>
</tr>
<tr>
<td>Learning capacity</td>
<td>3.62</td>
<td>3.49</td>
</tr>
<tr>
<td>Collaboration</td>
<td>3.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Communication</td>
<td>3.9</td>
<td>3.67</td>
</tr>
<tr>
<td>Focus</td>
<td>3.56</td>
<td>3.55</td>
</tr>
<tr>
<td>Media</td>
<td>3.47</td>
<td>3.6</td>
</tr>
</tbody>
</table>

5. **Clients Satisfaction:** The real client also evaluated the deadlines, the achievement of the goal, the quality of the work, if the team had a good communication during the process, the agility of the team and for last, the innovation. The average grades of both teams were very close. Team A had an average grade 7.91 and team B with 7.41.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Team A</th>
<th>Team B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Objectives</td>
<td>8</td>
<td>7.5</td>
</tr>
<tr>
<td>Quality</td>
<td>8.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Communication / Transparency</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Agility</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Innovation</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Media</td>
<td>7.91</td>
<td>7.41</td>
</tr>
</tbody>
</table>

F. **PBL Plan**

It contemplates all the training details, as local, date, hour, Teachers/Tutors, educational goals, subjects, giving a clear vision of the training performed.

Before the training we take some lessons as learned, which are:
- The lab environment was not agreeable so that the Students could reunite, when they got out of the lab to have meetings;
- The lack of time limited the interaction between them, because the training was applied in two consecutive days;
- Lack of Commitment of a Student made one of the teams unstable;
• Flexibility and unpredictability of approach favours
the improvisation, and;
The learning method motivates the Students to learn and
also to contribute effectively in the learning process.

VI. CONCLUSIONS

The developed the process validated the application of PBL
presented in this article, where it attempted to evaluate a
training course in Software tests engineers, emphasizing the
usage, based in used practices in the market, aiming at proving
how effective a methodology that preserves principles, such as
resolution of real problems inside real environments, with a
minimum cost.

Before the authentic evaluation we had different evaluation
points about the teams, providing a continuous feedback of
improvement points for Students and tutors as well. It was
shown that the individual and group work of the Students
contributed to the development of specific improvements for
each person, considering the evaluated criteria in the job
market.

Finally, the case study presented successfully achieved its
objectives: of the twenty subscribers, 70% of the Students
attended and only 15% of those quit on the second day of
training. Therewith, we formed an amount of twelve Students
qualified in Software test with emphasis in usage.

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