PBL Planner Toolkit: A Canvas-based Tool for Planning PBL in Software Engineering Education

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Abstract: The PBL (Problem-Based Learning) methodology provides many benefits to those who use it in teaching. In this light, it is important to plan well when using this methodology, efficient to the purposes established by an educator. However, there is a lack of specific tools to help educators in the task of planning their teaching, specifically geared to the PBL approach. As a solution to this problem, this paper proposes a tool consisting of a Canvas PBL and a set of cards intended to guide the planning of teaching in the PBL approach. Initial results indicate a good level of acceptance of the tool, as well as indicators of its utility in planning and adopting PBL, as shown by the data collected from the application of a survey that evaluated the use of our Toolkit.

1 INTRODUCTION

The alignment between the professional IT profile required by the labor market, in particular of the software industry, with the profile of graduated students from Computing courses has been shown to be a great challenge (Von Wangenhein and Silva, 2009), (Schuster, 2008). The challenge of reformulating academic curricula brings the proposition of skills development such as problem solving and business vision, but without overlooking, as well, technical skills that are part of the curriculum, such as programming and software development tools.

The ACM/IEEE published in 2012 a report of curricular guidelines for degree programs in Computer Science (Draft, 2012) and, in this report, there is a chapter entirely devoted to the characteristics of the graduates, specifically about skills which graduates must attain at least at an elementary level. We can mention as example of such skills like ability in project management; problem solving through alternative solutions and skills focused on oral and written communication, collaborative and interactive work.

Nonetheless, the courses that are based on traditional model of teaching, based on fixed transmission of knowledge, are not succeeding to promote effectively meaningful learning, nor encouraging students in the acquisition of new knowledge and skills necessary for adequate training (Luckesi, 2011).

As an alternative to the traditional model of education training, the teaching methodology in Problem-Based Learning - PBL (Striegel and Rover, 2002) has been applied in different areas such as Medicine, where it first started, and in Engineering and Technology. The PBL method is appropriate for education in Computing, because it significantly unites the initial training of students with professional practice, including professional skills in the curriculum, thus enabling them to develop their skills in practice (Ribeiro, 2005).

However, the adoption of the method is not trivial. Challenges are found particularly in terms of managing the teaching and learning process, since PBL differs a lot from the traditional and demands some changes, not only in the student and professor roles, but also in the learning environment, which needs to reflect the reality of the labor market (Rodrigues, 2012). The methodology prescribes that the problem, as the thrust of the teaching and learning process, (Savery and Duffy, 1995) is real; in other words, problems are not invented or created for the classroom. Instead, they are relevant and complex enough so that the educational goals defined by educators can be attained by students.

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And, last but not least, assessments should be conducted continuously to provide feedback on the performance of students in different perspectives such as: professors, tutors, clients and teammates (Tuohi, 2007).

With so many aspects and stakeholders to be considered for the adoption of PBL in a course, it became evident that is not an easy and obvious task. The risk of the PBL methodology implementation not being effective is high, especially if planning and monitoring is not conducted so as to ensure an alignment between theory (specificities of PBL methodology) and practice (as the methodology happens) (Figueiredo et al., 2011). So, to mitigate such risks and problems, the course planning in PBL approach must be careful, thorough in a way to contemplate all aspects inherent to the PBL methodology cited previously, and collaborative, to enable all the stakeholders (coordinators, teachers, tutors and clients) to work together, each one fomenting the work to the best of their abilities. To achieve the desired benefits that the methodology can provide to all involved, communication should be aligned among all stakeholders so there is no deviation of understanding of what is being planned and planning must be consistent with the principles of the PBL methodology.

2 THEORETICAL BACKGROUND

The Theoretical and methodological background that substantiate this research are presented in this section.

2.1 PBL Approach and Its Principles

PBL (Problem Based Learning) is a teaching and learning method that aims at the acquisition of knowledge as well as at the development of attitudes and skills through problem resolution. The PBL methodology is based on principles (Santos, Figueiredo and Wanderley, 2013). In a research (Rodrigues and Santos, 2013) performed from 4 key studies, 10 essential principles in PBL, that are a guide to an effective approach were defined. The 10 principles are:

1. All learning activities must be anchored on a task or problem; 2. The learner should feel that he/she owns the problem, and is responsible for his/her own learning; 3. The problem should be real; 4. The task and the learning environment should reflect the reality of the professional market; 5. The learner needs to own the process used to work out the solution to the problem; 6. The learning environment should stimulate and at the same time challenge the learner's reasoning; 7. The learner should be encouraged to test his/her ideas against alternative views and contexts; 8. The learner should have the opportunity and support to reflect on the content try, and the learning process; 9. The learning is collaborative and multidirectional; 10. PBL is supported by the planning process and continuous monitoring.

In (Santos, Furtado and Lins, 2014), the authors propose the distribution of the 10 principles in 5 key elements to be exploited in the adoption of the PBL methodology: problem, environment, content, human capital and process.

2.2 Planning Teaching Process and Learning PBL

Whoever decides to adopt the PBL method can benefit from positive results in the learning process. Among these results, students' development is heightened reasoning ability in solving problems; the students' stimulus in self-development of their autonomy and proactivity; high attendance and knowledge acquisition and elevation of the motivation and engagement (Khairiy Ah, Mimi and Azila, 2004).

However, adopting the PBL method is not a simple task. It proposes a change in the paradigm of teaching and learning that completely breaks the traditional teaching model (Schilling, 1998). It requires a change of attitude from students and professors, administrative support and infrastructure remotely appropriate, so when implementing it, all benefits previously mentioned can be achieved (Silva and Delizoicov, 2005). Another aspect is that the adoption of PBL is not prescriptive, that is, there is not a formula to be followed for the method adoption (Maltese, 2012).

Therefore, it is essential to plan for the adoption of PBL, in order to prevent the inadequate use of the method, negligence of critical aspects of the processes contained in learning methodology for its correct implementation and proper alignment between theory and practice throughout the learning and teaching process.

But in the current teaching practice, the activity of planning, in general, has not received its due attention. Actually, it has been considered a bureaucratic activity, too extensive, and of little help in teaching (Fusari, 1998). Thus, this research argues

that the adoption of the PBL approach should be performed from a management model that is driven by processes.

Researches such as (Santos, Montes and Rodrigues, 2013) and (Santos, Furtado and Lins, 2014) show that the effectiveness of the adoption of the PBL approach can be achieved when it is guided by defined procedures and stages of planning, implementation, monitoring and continuous evaluation for improvements. These steps are the same as defined in PDCA cycle (Plan, Do, Check and Act), a tool used in planning and processes of continuous improvement, that can be used also for management of the process of teaching and learning in PBL (Rodrigues, Estivalete and Lemos, 2008).

In the adoption of the PBL approach some aspects such as flexibility and unpredictability should be considered mainly as the impact on the stages management and activities associated with the teaching and learning process. Since PBL is a process-oriented approach (Alessio, 2004) it is fundamental that the alignment is maintained within the stages of the PBL process to ensure its effectiveness.

Based on the PBL principles the PDCA cycle (Plan, Do, Check and Act) and concepts associated with the technical 5W2H, an approach called xPBL, was developed, which will be detailed in the following section.

2.3 The xPBL Methodology

xPBL is a methodology that aims to align methods and tools for managing the PBL approach to education in fields such as Computer Science, in order to ensure that the principles are respected in its adoption. It was officially defined and proposed in 2014, but researches that supported its creation only started in 2006 (Santos, Furtado and Lins, 2014). To ensure that PBL principles that go beyond its educational objectives are met, the methodology xPBL is based on five elements: (1) Problem; (2) Environment; (3) Content; (4) The human capital and (5) Process. These elements reinforce ten principles that were established in (Santos, Figueiredo and Wanderley, 2013).

The elements of the xPBL methodology should be addressed at all stages of the PDCA cycle, mainly with regards to planning being aligned to its implementation. To help the planning process and guide the definition of 5 elements of xPBL, it is also used 5W2H technique: "What?", "Who?", "Where?" "When?", "Why?", "How?" and “How Much?”.

To help planning, the authors proposed a guide for each element of xPBL containing 7 questions about the 5W2H technique, plus a field called Output, which is a suggestion of formalization after completion of planning of each element.

3 PBL PLANNER TOOLKIT

The PBL Planner Toolkit or (PBL Toolkit, in short), is a tool to support teaching planning with the PBL approach in Computing courses. It is composed by a canvas (table) divided into fields and a set of cards that guide the completion of the canvas and of planning. The tool is intended to be used by all educators who wish to carry out teaching planning in PBL Computing courses. Especially novice professor who have low experience in conducting educational planning, professor with low level of knowledge in the PBL approach or both. Each component of this tool is presented in the following sections. A digital version of PBL Toolkit is available at http://www.pblplanner.com.

3.1 PBL Canvas

The PBL Canvas consists of a table divided into 11 fields. The definitions of the fields that form the PBL Canvas originated from the concepts of the PDCA methodology and xPBL. Its structure was inspired on the Project Model Canvas (PM Canvas) (Finocchio Junior, 2014). Each field has a color and an icon to facilitate its identification. The model of the PBL Canvas is presented in Figure 1 below.

Figure 1: PBL Canvas.

For each field, a color and a different icon were assigned, in order to facilitate its distinction, as well

as to ease the association with the PBL Cards. Each field represents a set of aspects to be considered in planning. These aspects are described below.

Table 1: The canvas fields and their aspects.

Icon/Field	Aspects
F1 - Course	Course contextualization defined items such as name of course, duration, type, target audience; prerequisites for study are described in this field.
F2 - Objectives	Goal setting for students' learning, goals related to motivation, engagement and students' attendance as well as the overall performance of the group. Definition of goals related to employability and professional performance of student.
F3 - Success Indicators	Student, methodology and course definition of indicators of success.
F4- Problem	Capitation, systematic description, submission, approval of the proposal of the problem and change of choice in the matter.
F5 - Environment	Definition of equipment, software and materials necessary for implementation of course; definition of the physical and virtual space.
F6 - Human Capital	Definition of roles and the team that will be part of the course.
F7 - Content	Description of the contents of a module. Indication of sources to support or deepening of knowledge.
F8 - Assessment Learning	Assessment that covers various aspects such as: content, customer satisfaction, process of resolution of the problem, result of problem solving, interpersonal skills, performance.
F9 - Processes	Description of learning process based on resolution of problems and process of dividing students into groups.
	Definition of timetable, professors and students assessment schedule, delivery of materials requested by the
F10 - Schedule	teachers, assessment of the methodological objectives and assessment of course quality.
F11 - Risks	Identification of risks and threats that may compromise the success of the course.

Many aspects have to be considered in the PBL Canvas. Therefore, thinking of a way to help the user during the course planning, it was decided to create of a set of cards, containing all those described aspects.

3.2 PBL Cards

40 cards were created and distributed among the 11 fields of PBL Canvas. Each of the 40 cards has the same structure. The front of the car has basically three pieces of information from the PBL Canvas: the name of the field; the color and icon that connects to the field. This was done to facilitate the association among cards and their respective fields in the PBL Canvas. Therefore, all cards from the same field would have the same color and the same associated icon.

Figure 2 shows the back of the cards' structure, which contains six important pieces of information: name and icon of the related field to the Canvas; name, card identifier and a card description; the questions that guide the completion of the PBL Canvas and examples of answers to the questions. Lastly, the artifacts that can be generated when planning.

Figure 2: PBL Card Verse Example.

The question item contains queries that have been defined to promote reflection in aspects that are necessary for the planning. In formulating questions the technique used was the 5W2H. However, the queries that compose the cards are not restricted to those that are part of the technique, allowing queries that contribute best to the aspect to be planned.

On the other hand, the examples item represents possible responses to each one of the questions made

in the referred item. The purpose is to illustrate, for those who carry out the planning, what kind of response is expected for each question.

The artifact item refers to the field Output from the proposed guide in article (Santos, Furtado and Lins, 2014), which defines the xPBL methodology. As well as in the guide, this item represents a suggestion of a planned aspect formalization or support tool during its implementation.

3.3 How to Use the PBL Toolkit

Course planning with the PBL approach using the toolkit is divided into 3 phases: Planning, Revising, and Sharing, described below.

3.3.1 Planning

Planning is subdivided into 3 stages that must be performed at least once each one. To carry out this stage it is important that there is participation of the people who will act as teachers, tutors and coordinator.

The stage 1 in completing the PBL Canvas is the introduction to planning. It is composed of the fields Course, Objectives and Indicators of Success, in this order. These fields define the context of the course to be planned as well as the objectives and goals to be achieved. Planning participants should answer questions 1 through 9 and set responses in the corresponding fields. After setting the answers to chart 9, step 1 of planning is finalized.

Stage 2 corresponds to the fields that come from the xPBL methodology: Problem, Environment, Human Capital, Content and Learning Assessment. These are the central elements of planning and are more closely related to the PBL method. It is from the planning of these fields that the methods and tools for managing the PBL approach in Computer teaching will be aligned. The process of filling in is identical to the one in step 1 starting on card number 10 through 33.

Finally, stage 3 completes the planning with the Process, Schedule and Risks fields. These fields together are responsible for defining the learning process based on problem solving to be followed, class schedules, scheduling of assessments and deliveries, as well as identifying possible risks that threaten the success of the course as a whole. The letters to fill this field range from number 34 to 40 and after letter number 40, have been answered the completion of PBL Canvas will be completed. Figure 3 shows the finished PBL canvas.

Figure 3: PBL Canvas after completed planning.

Table 2 below presents some questions and answers regarding the planning of a course in Computer Science.

Table 2: Example of questions and answers of planning.

Fields	Some example of questions and answers
F1	Area of Activities? A: Software Engineering. Work schedule and duration of course? A: 60 hours in 4 months.
F2	What non-technical skills (personal, management and business)? A: Leadership, teamwork, initiative, communication, innovation, business processes.
F4	What information should be included in the description of the problem? A: Mastery of the problem, public target, needs of the clients, importance of the problem.
F6	Who will be the client? A: Company XYZ. In what way will he/she be involved? A: In the workshop of opportunities, evaluations of satisfaction and final presentation.
F8	What criteria will be used to evaluate the content? A: Understanding the basic concepts of the projects, the life-cycle, processes and critical factors.
F9	What are the criteria for splitting up the teams? A: Level of training, skills, professional experience and close affinities. What learning process should be followed? A: The 4-stage Barrows PBL (Proposing, Discussing, Resolving and Assessing).

3.3.2 Revising

The purpose of the review phase is to check issues that have raised questions during planning as well as some aspect that has not been fully answered. It is also important to make sure that the dependencies between the fields are properly aligned. For example the objective fields with those of evaluations in which the first defines the objective and in the second how to measure if it has been reached.

3.3.3 Sharing

The final phase aims to build an action plan that should list all tasks and artifacts planned during the planning phase. The action plan should contain, in addition to the task list and artifacts, the deadline for creation, the status of the task or artifact, and who is the owner. With the creation of the action plan, a version of the teaching plan is generated (baseline), which can undergo adaptations and improvements throughout its implementation.

4 RESULTS AND DISCUSSION

Next we present the first results obtained with the assessments of the PBL Planner Toolkit. The strategy adopted for assessment was to evaluate the Toolkit by its constitutive features and evaluate the use of the Toolkit as a education planning tool in the PBL approach.

The methods used to obtain the first impressions were a survey based on expert opinion along with workshop. The survey consists of an online questionnaire in which we adopted the Likert scale five propositions with the following possible values: -2, -1, 0, +1, +2, indicating: disagree totally, partially disagree, neutral, partially agree and totally agree, respectively. In this research, the results are obtained through the collection of perceptions and feedback of professors who already have experience in planning in education PBL approach.

In all, six aspects were evaluated: Usability, Functionality, Design, Understanding, Work Collaborative and Satisfaction. The objective of this assessment for every assessed aspect and some questions is described below:

Usability: To assess the level of the tool usage.

Q1 – It is easy to use the PBL Canvas Toolkit for planning.

Functionality: To assess the compliance of the PBL planning use adoption.

Q2 - I found the PBL Planner Toolkit appropriate as a tool for course planning.

Design: To evaluate forms and legibility of the Toolkit.

Q8 - The cards texts are legible.

Understanding: To assess the degree of ease understanding and comprehension of the rules for the tool usage.

Q10 - The Cards are easy to understand its use.

Collaborative Work: To evaluate aspects of communication, cooperation and collaboration among those involved in the planning.

Q12- PBL Planner Toolkit has enabled a better COLLABORATION during planning.

Satisfaction: To evaluate the perception of satisfaction and pleasure in the use of the Toolkit.

Q15 - I recommend the use of PBL Planner Toolkit for planning.

The results were obtained through the realization of 3 educational planning workshops in 3 higher education institutions in the State of Pernambuco/Brazil with professors from Information Systems and Computer Science courses. Each workshop had a total average duration of 3 hours and consisted of the concepts presentations and the PBL approach and the presentation of the PBL Canvas Toolkit which was explained to what was proposed and how to use it. Soon after the presentations, the professors present in the workshop were divided into groups of up to 5 members and were asked to collaboratively carry out a teaching plan for a course of their choice using the PBL Canvas Toolkit.

After the planning completion the questionnaire was sent through a link, so the professors could answer the evaluative questions about the Toolkit. In total, 34 professors participated in the workshops and 14 of these answered the questionnaire.

These 14 teachers represent significantly the target audience of PBL Toolkit. With respect to the professors' profile, there were 5 doctors, 5 masters and 4 specialists; 10 professors with average teaching experience time of 4.5 years and 4 professors with an average of 23.5 years of experience; 4 professors work in public institutions and 10 in private institutions. Regarding knowledge of the PBL approach, 7 professors claim to possess a low knowledge, 5 professors with average knowledge and 2 professors with high knowledge. The responses are consolidated in Table 3.

Table 3: Responses of the professors.

Aspects	Questions	-2	-1	0	1	2
Usability	Q1	0	2	3	3	6
Functionality	Q2	0	0	2	3	9
	Q3	0	1	4	5	4
	Q4	0	0	3	2	9
	Q5	0	0	2	2	10
	Q6	1	0	2	2	9
Design	Q7	0	1	2	3	8
	Q8	0	2	3	4	5
Understanding	Q9	0	2	2	3	7
	Q10	0	2	2	3	7
Collaborative Work	Q11	0	0	2	4	8
	Q12	0	0	2	3	9
	Q11	0	0	2	2	10
Satisfaction	Q14	0	0	3	0	11
	Q15	0	0	2	1	11

The Usability aspect had only a single question (Q1) which served to measure the professors' perception of the ease of use of the Toolkit. Six professors totally agreed (42.86%) that it is easy to use the Toolkit to plan and other 3 said that they partially agree (21.43). Adding these two scales we will have 64.29% of the total of respondents which indicates a good usability index.

On the Functionality aspect, overall, 59% of the professors indicated that they fully agree with the questions that evaluate the aspect. This indicates that the Toolkit has suitable characteristics and features for educational planning activities (Q2) such as completeness (Q4), reflective thinking (Q5) and better structuring and sequencing of activities (Q6). However, question 3 (Q3), that evaluates the flexibility of the Toolkit for changes did not obtain a score compatible with the other issues regarding the Functionality aspect. We believe that the flexibility was somewhat compromised due to dependencies that are created between the fields of the Canvas, such as the planning is being carried out. For example, the relationship between objectives and indicators of success. It is likely that having the removal or alteration of an item from one of these fields will need to reflect the change in the other field as well.

The Design aspect only evaluated characteristics of the cards. Question 7 (Q7) verified the appropriateness of the card size, and obtained 8 professors who totally agreed (57.14%) and another 3 who partially agreed (21.43%). This added gives us an approval percentage of 78.57%. However, question 8 (Q8) which evaluated the readability of the texts of the cards obtained 64.28% of approval, adding the professors who totally agreed (35.71%) and partially (28.57%). It is understood that because the cards are still a prototype and paper type is still not definite, the approval percentage could increase, once readability is improved.

The Understanding aspect also has two questions. The first (Q9) evaluated how clear the instructions were and the use of the Toolkit and the second question (Q10) evaluated how easy it was to understand how to use the cards. Both questions obtained the same response reaching 72% approval adding professors that totally agree (50%) with those who partially agreed (22%).

The penultimate aspect assessed was the Collaborative Work containing three questions. The first one (Q11) evaluated the communication promoted by the Toolkit and obtained 57.14% of the professors totally agreeing and another 28.57% partially agreeing. This resulted in 85.71% of approval. The following questions (Q12) that evaluated the collaboration and (Q11) that evaluated the cooperation obtained the same indices of question 11, that is, 85.71% of the professors confirming the contribution of the Toolkit in the aspect of collaboration and cooperation during planning.

The last aspect assessed was Satisfaction through two questions. The first question (Q14) evaluated the pleasure of the professors in using the Toolkit and obtained 78.57 % approval. Same index for the next question (Q15) that evaluated whether professors would indicate the Toolkit to other professors who wished to use it to carry out planning.

5 CONCLUSIONS

The PBL Planner Toolkit presented in this article aims to assist educators who wish to conduct educational planning in the PBL approach through a Canvas and a set of 40 cards that guide the filling of the Canvas. The relevance of the proposition of a tool to support teaching planning in PBL lies in the shortage of specific tools for this purpose, especially in the PBL approach. The diversity of aspects to be considered in teaching planning with PBL reinforces the need of support tools in this task so that the planning is carried out in the best possible way.

The proposal for the creation of a specific canvas for the PBL approach using xPBL as the core methodology was to unite the positive characteristics provided by the Canvas technique such as collaboration, holistic vision, communication, and to

safely preserve PBL principles through a PBL methodology focused on Computer Science.

The initial results of the PBL Planner Toolkit validations indicate very positive possibilities regarding the productivity and usability of its use for the teaching planning in PBL approach. As a point of improvement, the evaluations indicate adjustments regarding the relation between the fields and the readability of the card texts. A more thorough assessment of the aspect of usability is also needed. On the other hand, the positive aspects highlight the Collaborative Work aspect, since the educational planning in the PBL approach must be carried out so that all the stakeholders involved participate. And so it is important to have communication, collaboration and cooperation because those are the three pillars for collaborative work and the contribution given by the Toolkit and professors who participated was acknowledged.

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