A Systems Approach to Managing Learning based on Bloom´s Revised Taxonomy to Support Student Assessment in PBL

Ariane Nunes Rodrigues
Universidade de Pernambuco
Recife, Brazil
ariane.rodrigues@upe.br

Simone C. dos Santos
Centro de Informática
Universidade Federal de Pernambuco
Recife, Brazil
scs@cin.ufpe.br

Abstract—The dynamism and intensity of practices inherent in problem-based learning (PBL) can end up having an adverse effect on teaching practices. The difficulty in defining clear educational objectives aligned to appropriate forms of assessment is also a recurring challenge in the management of learning environments. As a response to this state of affairs, this paper presents an approach to a system for managing learning based on PBL that makes use of Bloom's revised taxonomy to support planning and assessment activities. The model was implemented using prototypes with low-fidelity screens and its applicability with regard to the conduct of teaching using PBL was found to be valid.

PBL: Systems for Managing Learning (SML); Bloom’s Taxonomy – Revised; Planning and Assessment Processes.

I. INTRODUCTION (HEADING 1)

The dynamism and intensity of practices inherent in problem-based learning (PBL) [1] can end up having an adverse effect on teaching practices. On the one hand, a lack of control over teaching activities, the essential elements of which are processes (i.e. managing the application of the method), people (especially new roles involved) and tools (the teaching environment itself and the availability of the technology needed), can negatively affect the PBL approach and its principles. On the other hand, the difficulty in defining clear educational objectives aligned to appropriate forms of assessment can undermine the perception and evaluation of the results of teaching and learning.

Therefore, it is believed that many of the challenges that PBL presents are linked to new ways of “teaching” and how “assessment” is aligned to PBL principles. The dynamism of the learning method, the focus of which is on solving problems, requires more appropriate ways to assess students, since assessment is very subjective. The flexibility and unpredictability present in practices lead to control being lost over the planning and monitoring of tasks and the results of teaching and learning.

As a response to this state of affairs, this paper presents a systems approach to managing learning based on PBL that makes use of Bloom's revised taxonomy to support planning and assessment activities.

This approach argues that Systems for Managing Learning (SMLs) can be used to determine what resources need to be used to facilitate how teaching activities are managed, especially the planning of teaching and the assessment of students. Besides directly aiding faculty in their teaching practice, SMLs are powerful tools because they facilitate collaboration and communication between those involved in this process.

Even though the use of SMLs has been little explored as a support to the PBL method, the literature has already recorded some advantages of implementing and using them, especially with regard to the ease with which they can be used to oversee and monitor learning. In the context of PBL, support to the monitoring of group tutorials is “better” via a SML [2], because less time requires to be spent on facilitating in addition to which an SML provides faculty with the means to monitor and offer guidance by making observations and giving feedback continuously. However, as is well-known, the success of management systems heavily depends on the processes thus implemented being regarded as effective.

One of the most critical processes in PBL is to align educational objectives to assessment. As these objectives are statements that express changes to be brought about by learning, checking whether such objectives have been achieved can be ensured by ensuring that appropriate assessment instruments are applied.

It happens that in practice, the assessment process has been used inappropriately with a view only to classifying knowledge. In addition, it has been established that these elements are incompatible. The real point of assessment is to assist teachers to identify what difficulties students have when they are learning. It is to seek to meet these objectives that the definition of processes within the systems approach is based on Bloom’s revised taxonomy [4], the purpose of which is to support teaching practice. The idea is to ensure that educational objectives are aligned to assessment during the planning of teaching in the real environment of learning, thus contributing
II. TECHNOLOGY APPLIED TO PBL EDUCATION

A process inherent to learning in PBL is to tackle problems which have a complexity that is similar to real situations. This fosters students’ motivation as well as their developing the skills and attitudes needed to solve them [5]. Learning tasks which are primarily functional ones keep students immersed in practices which are always supported by content. By considering themselves to be active agents in the process [6], students focus on solving problems through collaborative learning by debating with each other and expounding their ideas. The dynamism, flexibility and unpredictability associated with this approach to learning require greater attention from teachers, mainly to ensure the approach is being effective. Because its essence is to be strongly oriented to processes [6], it becomes necessary to consider how to manage them. Thus, adopting this approach to teaching can only be effective when teaching is planned and monitored such that the alignment between the content (theory) and the problem (practice) may be guaranteed. In addition, assessment must be appropriately applied.

Just like learning, assessment in PBL takes different forms. Self-assessment and constructive peer assessment are considered important for the metacognitive process, because this enables a student to undertake an assessment of his/her perceptions, strengths and weaknesses, as well those of his/her peers [7]. Furthermore, the possibility of assessing how the student applied his/her knowledge and performed during the resolution process is stressed. Besides these, authentic assessment [9] as a strategy inherent in PBL aims to stimulate critical thinking and insight during problem solving, and to train students to reflect on different ways to solve a problem.

Therefore, this article argues for the idea that the effectiveness of the approach depends on its processes being managed efficiently. Similarly, management of the conduct of teaching practice should consider the relationship that exists between the educational objectives, procedures and assessment in order to ensure the quality of a degree course in PBL. In this context, the application of appropriate technology to support these processes could be make a great difference.

Technology is ever present today and this includes new teaching practices being driven by it. However there is only a small number of studies on learning that refer to the use of management systems as support to learning based on problems. According to [9], computational tools and computers have not been explored extensively for PBL. Therefore, this section briefly presents studies that evidence there are systems that target the application of PBL.

A collaborative learning environment, deemed a PBL-VE, the acronym for Problem-Based Learning Virtual Environment, is presented in [9]. This system enables PBL tutorial sessions to be supported both face-to-face and at a distance. The participants in the initial applications, which aimed at improving the development of the environment, were Computer Engineering students from the State University of Feira de Santana (UEFS).

The “PBL Manager” is a support system for education on the Web which sets out to provide a teacher with the facility of storing problems in a shared database [10]. With a view to computerizing the process of drawing up problems, the system also allows editing, searching for and sharing information.

In [11], a proposal is put forward for an environment based on PBL principles and on the CBR (Case-Based Reasoning) approach and which, by using the DUMBO system, seeks to facilitate the teaching of Computer Networks. The AAERO (the acronym in Portuguese for a Learning Environment for Teaching Computer Networks Oriented towards Problems) considers functions that are basic to the actors of the teaching and learning process. In addition to supporting student learning and the PBL process, by making various resources available, the environment provides such functions as "developer of the problem", "tutor" and "assessor" to the teacher. Its construction draws on the researcher’s analysis of other environments specific to PBL, such as BELVEDERE, CROCODILE, CALE, CoMMIT and Munics.

The thesis of [12] puts forward a strategy model of teaching and strategy based on PBL and was applied in a virtual learning environment. The model is integrated with different resources that can be customized to the different actors of the process as a means to facilitate their interacting with each other in the environment. In addition to the collaboration tools, in which what prevail are activities using forums, chats and discussion lists, there is "My Space", "Support" and "Help". The first relates to managing and organizing information and provides the "Personal Library", "Notes" and "My Data". As for the support, this supplies resources to search for data cataloged in the environment as "ABP Bank", "Solve APB", "Guide Bank for solving APB" and "Guide to resolution."

The results of these studies showed support activities that involve teaching practice were superficial, especially regarding the planning of teaching and consequently the assessment process. Even though it was confirmed that performance was being monitored in order to support the assessment, there is no means to ensure that performance is being defined and monitored appropriately in these environments.

Therefore, this article emphasizes the importance of encouraging planning in the management system itself by clearly defining the educational objectives in addition to aligning these to the different forms of assessment. It is evident there is a need to develop management systems for a total PBL application, i.e. systems that can support not only student
learning but also teaching practice. Towards an appropriate model to set this aim, The revised version of Bloom’s taxonomy is adopted with a view to seeking to ensure that the model that sets this aim is appropriately designed. This tool is suited to PBL education because the philosophy behind is broad, ranging from metacognitive aspects to constructivist theories, as required by PBL, and emphasizes the relationship of knowledge with awareness of how the individual learns.

III. BLOOM’S TAXONOMY – REVISED VERSION

Bloom’s taxonomy [13] is a classification scheme that enables educational objectives to be formulated and organized at cumulative and dependent levels, as shown in Fig. 1.

![Bloom’s Taxonomy of Educational Objectives.](image)

The educational objectives are represented by statements that express what the student can be expected to achieve, and makes modifications to learning explicit for the teaching and learning process [13].

When considering metacognition and self-learning, the taxonomy undergoes considerable changes and is deemed the “revised” version [14]. Having been made to fit the new forms of learning, including PBL itself, the taxonomy aims at "knowing how to" deal with the procedures in solving problems rather than "knowing what" to do on what content.

A very noteworthy change in its structure, with regard to cognitive processes and knowledge processes, can be represented by a two-dimensional table (see Fig. 2).

![Figure 2. Bidimensional Table of Bloom’s Taxonomy Revised.](image)

From the cognitive point of view, each one of six verb forms has a specific meaning and is associated with verbs in the gerund:

- **To remember**: to recall, to recognize or to reproduce ideas and contents. Associated verbs: Recognizing, Reproducing.
- **To understand**: to explain an idea, concept in one’s own words. Associated verbs: Interpreting, Exemplifying, Classifying, Summarizing, Inferring, Comparing and Explaining.
- **To apply**: to apply a piece of knowledge, a procedure to a new concrete situation. Associated verbs: Carrying out, Implementing.
- **To analyze**: to divide information into parts and to understand the inter-relationship between them as well as in the overall structure. Associated verbs: Differentiating, Organizing, Attributing, Concluding.
- **To evaluate** (representing of Assessment): to undertake judgments based on criteria, standards and norms. Associated verbs: Checking, Critiquing.
- **To create** (representing of Synthesis): to reorganize elements in order to create a new vision, solution, structure and coherent model, from knowledge and skills previously acquired. Associated verbs: Generalizing, Planning, Producing.

From the knowledge point of view, the model has four dimensions:

- **Effective/Factual**: This type of knowledge is very useful for enabling familiarization of a discipline to be gained by using the basic contents. **Subcategories**: Knowledge of the Terminology; Knowledge of specific details and elements.
- **Conceptual**: Knowledge related to more elaborate contexts. The students can explore / discover the interrelationship between elements. There is evidence of explicit knowledge regarding classification and categorization as well as knowledge of theories and structures. **Subcategories**: Knowledge of classifications and categories; Knowledge of principles and generalizations and; Knowledge of theories, models and structures.
- **Procedural**: Knowledge related to the use of techniques, methods, criteria and algorithms. This type of knowledge refers to "how to do something." Use of criteria of "how" and "when" to use a specific procedure. **Subcategories**: Knowledge of the skills specific to the disciplines and algorithms; Knowledge of specific subjects with techniques and methods; Knowledge to determine the criteria needed to show that procedures are being used appropriately.
- **Metacognitive**: Knowledge related to interdisciplinary. To use previously assimilated (interdisciplinary) knowledge to solve problems and / or to choose the best method, theory or structure. **Subcategories**: Strategic Knowledge; Knowledge about cognitive tasks, including contextual and conditional knowledge; Self-knowledge.

The idea of a two-dimensional table is to interpolate the categories when educational objectives are drawn up, by combining the type of knowledge to be acquired with the cognitive process (skill to be performed). In this case, it is
considered that it is essential both to understand and differentiate between cognitive and knowledge processes.

IV. ALIGNING EDUCATIONAL OBJECTIVES AND ASSESSMENT

With the purpose of supporting PBL teaching practice, an alignment model seeks to ensure that the educational objectives and assessment remain aligned throughout the teaching and learning process. Based on the revised taxonomy along with the two-dimensional table, the model facilitates the planning of teaching as it supports defining the educational objectives, in addition to checking the alignment of these components. The following sections describe the alignment steps defined in the model, including a framework for defining the educational objectives, which relates cognitive processes to those of knowledge and associates a form of assessment with this. In addition it applies this model to the Amadeus SML.

A. Stages of Alignment

To guarantee alignment in the PBL approach, the model was structured into four distinct stages: (1) Defining educational objectives; (2) Defining assessments; (3) Providing inputs for the two-dimensional table (Fig. 2) and; (4) Checking the alignment and identifying points for improvement.

Given that educational objectives are statements that express expected changes in learning, they should be structured by joining "verbs" and "nouns" as shown in Fig. 3.

The structure of an objective is initiated by a "verb of mental activity". These verbs express the intended action more efficiently, so what they enable to be defined is what cognitive process is expected to be reached by the educational objective, assuming the levels of "to remember", "to understand", "to implement", "to analyze", "to evaluate" and "to create". After determining the intended action, a "noun" is added which enables an item of content to be associated with the action. Then, the "verb in the gerund" clarifies "how" it is expected that this objective may be achieved and concludes with the "noun" which associates the gerund with one of the categories of the knowledge process, thus concluding the description of the objective. There still remains the relationship of the verbs of action and their associated verbs, in the gerund, as shown in Section III. When defining an objective, the choice of the verb of mental activity is crucial to defining how the objective will be achieved, and is always associated with the verb in the gerund.

Fig. 4 illustrates an example of an educational objective as per the structure proposed. Note that the verb of mental activity "to remember" is associated with "recognizing", a gerund, which shows the real intention of the educational objective.

To remember + the terms most used to define problems common to the functioning of a software program + by recognizing the distinction between them during the tests.

The step “To define assessments” aims to associate a form of assessment with each objective. In addition, the teacher should predict the time needed to do it, by setting a time befitting its complexity. In order to solve problems, for example, it is considered that the more complex the problem is, the more time should be set aside to resolve it and to conduct the assessment itself.

The step “To provide inputs for the two-dimensional table” aims to fill in the cells of the two-dimensional table, the inputs being the elements "Objective, Assessment and Time". Since the cells are formed by the intersection of the dimensions of the table, they can be filled in with two or more educational objectives. Similarly, the educational objective can occupy two or more cells in the two-dimensional table (Fig. 2).

The step “To verify alignment and points of improvement” aims to guide the teacher as his/her planning. After having completed the entries in the table, the teacher can verify and assess the alignment and/or misalignment of the elements mentioned by means of the “macro” vision provided by the two-dimensional table. The idea is to identify areas for improvement, such as "where" and "how to" improve the choices of planning actions in addition to reflecting on learning opportunities lost because of the presence of empty cells.

It is believed that these steps guide teaching practice, especially regarding how the structure defines the objectives. This enables the object to be adequately associated with the contents and the assessment. Since the table reflects a dual perspective, an argument is thereby made about the importance of teachers using it because this enables a) the impacts of the assessments and the consistency of the curriculum to be examined; b) to be given to aligning the objective elements and assessment; and c) the activity of the objectives to be differentiated [4].

B. Application of the Model in the SML

The alignment model was implemented in Amadeus SML1 by using prototypes with low fidelity screens. It was noticed that Amadeus does not have a module that allows teaching to be planned based on defining educational objectives and monitoring these. In this context, the prototypes presented in this section propose Planning and Monitoring activities in PBL as per the latest version of this system. Since the prototypes were originally written in Portuguese, they were adapted to this study so as to emphasize only the actions of planning. What mainly stands out is how to set educational goals and to integrate them into an assessment, besides checking that these elements have been aligned when planning teaching.

Planning is structured into three integrated steps. Planning begins by creating a "learning module", into which subjects can be put, activities defined and problems set up. After this has
been drawn up, the teacher should establish educational objectives and relate them to the module (Fig. 5). The structure, as per Fig. 3, assists the teacher in this action and enables “what students need to do” to be associated with the content, as well as how this will be acquired and the type of knowledge.

Planning is effectively concluded when the teacher defines the actions regarding assessment. The form of assessment for each defined objective should be selected, as should the criteria and time, as shown in Fig. 6. A problem may still be associated with the assessment stage after the objective has already been created, which means that the proposed problem, in a way, is related to the objective that the teacher wishes to achieve.

Having defined these actions, the teacher should check if the elements are aligned and/or misaligned (Fig. 7). After the terms “objective, assessment, and time” have been filled in, the two-dimensional table enables a teacher to identify cognitive processes that have not been explored, which makes teachers reflect on their planning. Because of the flexibility of the revised taxonomy, note that the educational objectives are located in two or more cells (Fig. 7) i.e. what is most expected from a student in terms of the mental activity he/she is expected to acquire.

V. VALIDATING THE MODEL

The validation of the model was based on interviews and supported by a questionnaire the purpose of which is to assess the suitability of the model. The screens that were designed served as an instrument of analysis in this process. In the questionnaire, besides the objectives of the screens, two...
assertions were associated with each of the objectives, with predefined values, using the Likert scale (1 – “I strongly agree”; 2 – “I agree”; 3 – “I’m undecided”; 4 – “I disagree”; 5 – “I strongly disagree”), followed by a question for comments. To make this clearer, the assertions of the screens shown in Figures 5, 6 and 7 are summarized in Table 1. Examples of assertions per screen.

<table>
<thead>
<tr>
<th>Screens and assertions</th>
<th>1. strongly agree</th>
<th>1. agree</th>
<th>1. I’m undecided</th>
<th>1. strongly disagree</th>
<th>1. disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to Amadeus</td>
<td>42.9%</td>
<td>42.9%</td>
<td>14.3%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Registering the course</td>
<td>28.6%</td>
<td>28.6%</td>
<td>14.3%</td>
<td>14.3%</td>
<td>28.6%</td>
</tr>
<tr>
<td>Planning the course</td>
<td>42.9%</td>
<td>0%</td>
<td>0%</td>
<td>14.3%</td>
<td>42.9%</td>
</tr>
<tr>
<td>Defining problems</td>
<td>71.4%</td>
<td>0%</td>
<td>14.3%</td>
<td>0%</td>
<td>14.3%</td>
</tr>
<tr>
<td>PBL Process</td>
<td>28.6%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Defining the Ed Objectives</td>
<td>71.4%</td>
<td>28.6%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Defining assessment</td>
<td>42.9%</td>
<td>0%</td>
<td>0%</td>
<td>28.6%</td>
<td>0%</td>
</tr>
<tr>
<td>Checking alignment</td>
<td>57.1%</td>
<td>42.9%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>PBL monitoring</td>
<td>57.1%</td>
<td>28.6%</td>
<td>0%</td>
<td>0%</td>
<td>14.3%</td>
</tr>
</tbody>
</table>

Validation involved the participation of seven experienced teachers, mostly at undergraduate level and who had basic knowledge of the Amadeus SML and basic knowledge (3), intermediate knowledge (3) and advanced knowledge (1) of the PBL approach. Table 2 summarizes the evaluation of the participants per each screen of the prototype. Due to limitations of space, their subjective comments have been omitted.

### TABLE I. SUMMARY OF THE VALIDATION RESULTS

It is believed that, although static, the prototype allowed the information from the model to be expressed by means of representing the design conceptually via arrangement of the contents, buttons, flow of the screens and support to planning activities.

In summary, the results obtained present in their totality the teachers’ acceptance and/or satisfaction with the screens and their goals. When considering the screen for setting educational goals, the teachers agreed that the structure is intuitive and that a coherent relationship is established between the elements. Besides understanding the proposed action, the teachers report they were able to relate the essential elements to their definition. Moreover, they also managed to identify the dependency of the objectives to the assessment on the “planning / defining the assessment” screen and they confirmed that the fields were clear and that it was easy to undertake the action. As to verifying the alignment, the teachers agreed that the two-dimensional table not only guides planning but also enables the alignment between the objectives and the assessment to be visualized.

### VI. CONCLUSIONS

The purpose of this article was to present a management systems approach to education in PBL based on Bloom’s revised taxonomy. With an emphasis on teaching activities, what stands out is the alignment model and the possibilities for defining clear and coherent educational goals associated with the learning module and the assessment itself. The implementation of the model proposed as an extension to the Amadeus SML was performed by using the prototyping technique. Since the teachers involved accepted both how to implement the model and the results obtained from doing so, this showed that aligning educational goals and assessment can be achieved. This made teaching practice in this environment easier and therefore given that the results were positive this shows that this approach is effective.

As to future actions, the functionalities of all the screens of this model are being incorporated into the new version of Amadeus after having been approved by its managers who did so based on this study.

### REFERENCES


[2] Camp, G. Problem-Based Learning: A Paradigm Shift or a Passing Fad? The University of Texas Medical Branch.


[10] Santos, J.A.M., et. al. PBL Manager: Uma ferramenta de compartilhamento de problemas para auxílio à metodologia de ensino PBL.(A tool for sharing problems that assists the methodology of PBL teaching) DOI= http://cassiovandenberg.academia.edu/joaocarlos


