

Problem-Based Learning (PBL): An approach of integrating acquired knowledge in mathematics and chemistry for effective classroom delivery

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ABSTRACT

In this paper, we present the concept of Problem-Based Learning as a tool of integrating the basic knowledge previously acquired in a chemistry lesson to the mathematical modeling of pH-metrics. In like manner, we consider how to use this technique to bring the knowledge acquired in a calculus lesson into teaching electricity in a chemistry class. It involves some level of brain storming. Here active learning takes place and knowledge gained by students either way through a collaborative learning situation becomes personalized within the group. This underscores the need for the integration of the curricular of some basic concepts in mathematics and the sciences in general from the school level, thus it makes it easier for students in the tertiary educational level to learn higher and applicable concepts. Problem-based learning method then becomes an enviable tool which can be used in teaching both Mathematics and Chemistry at the Secondary and tertiary levels.

Key words: Problem-based learning, active-learning, personalized knowledge, Collaborative learning, Calculus, integration of curricular.

INTRODUCTION

Traditional curricula are taught and therefore also learnt, in a fragmented nature (Bialek *et al*, 2004). Research shows that learners and students view Mathematics and Science as completely separate entities without realizing the links that exist between the curricula. This phenomenon has implications for teaching and learning in higher education as well as in schools (Hannan, 2000). Experience in teaching Mathematics in the University also show a highly skewed percentage failure rate in Elementary Mathematics of fresh men in the Universities tend towards students who major in other Sciences. Traditional curricula is facing pressure to become more integrated and interrelate since a blend of

knowledge is required for lifelong and meaningful learning. (Finucane *et al.*, 1998). Lifelong learning in general and demand for continuous development of skills, knowledge and attitudes needed in working life in particular, have resulted in a call for new ways to organize learning. The knowledge gained in education becomes quickly outdated and loses its value for working life. Working life requires new kinds of competencies including independent knowledge acquisition and application, problem solving, co-operative and multi-dimensional professional skills and abilities for continuing learning. Problem-based learning has been one of the approaches to bridge the gap between work and education. PBL is an educational approach that has been adopted in various educational institutions around the world. However, some people consider that PBL is not

adequate for mathematics, and other abstract sciences, since it does not guarantee absolute accuracy and promotes know-how more than what-and-why knowledge for abstract notions.

Characteristics of mathematics and chemistry problems

We must be sure of the type of applications to use for deriving a problem in Mathematics and Chemistry. This calls for the nature and characteristics of Mathematics and Chemistry in interacting applications. Of course there are specific characteristics of active learning in mathematics, and we must be aware of them when building a problem in mathematics, but clearly mathematics can be learned by using PBL. Here we discuss the possible important objection against Maths PBL: usually, in a PBL setting, one gives the students a real -life problem and students, in order to solve the problem, must find and study the notions required for solving the problem. How can we find a real -life problem in Maths? How can such a problem force students to study the notions ("what and why") and not only the consequences of the notions ("how to do")? Actually the answer is not so complicated. Two types of "applications" can be used. First a "concrete application" in this case it must be clear that the application is only a pretext to study math, and that main developments must be mathematical ones. This has the obvious consequence that a complete development must not be required in the application domain, on the opposite of course a complete development must be required in the math domain. In other words, professors as students must not forget that the main aim of the study is a mathematical one (see K. Ben Naoum *et al* , 2008).

In this paper, we shall consider an application which is easily understandable and which allows the integration of both Mathematics and Chemistry. Such applications only use the desired mathematics notions, and possibly not to require students to solve the real -life problem itself , and not to go beyond the numerical results(no "concrete production", in the application domain, is required). Quite often, physical notions are studied with a small number of variables (two or three for example, for computations to be done by hand). As an example,

we can re-use a problem already used by physicists needing to solve an order two or an order three linear system, transforming it to solve an order n linear system, and so needing to study some parts of linear algebra. The heat equation is often used in only one space variable in thermal lessons, and can be used in two space dimensions for a problem in a Partial Differential Equations PBL setting. No need in this case to build a robot or a rocket or any kind of "concrete" realization, but just to give the numerical results. The same applies to Chemistry concepts and the illustrative examples (PBL problems) in this paper reflects such cases. The characteristics of a well defined problem in Mathematics and the Sciences includes the following:

- A complex task to accomplish by brainstorming
- A need for several competencies that will integrate knowledge from Mathematics and Chemistry.
- The presentation shows no direct solution, otherwise it would just be a normal regular assignment.
- Requires students' involvement, initiative and team working.
- At least one learning obstacles should be presented.

Requirements for constructing a pbl in mathematics and chemistry teaching

In order to build a PBL, we must first define precisely which are the main aims of the course. Here we concentrate our efforts not in terms of contents, but in terms of competencies, and how the quest for personal knowledge in Mathematics affects/ interrelates with the quest for knowledge in Chemistry. So which are the abilities (the qualities) we want our students to develop? Below is a list which is not extensive, but are required for Mathematics, Chemistry and in fact most scientific subjects.

- Identifying some specific application areas for basic concepts.
- Personalising knowledge.
- Capture the sense and need for rigor, in both written and oral expression
- Grasp the need for abstraction and use it appropriately
- Prove, generalize, criticize results

- Model different situations by using the appropriate mathematical tools
- Interpret and assess results.

Of course we also need to develop some specific contents (such as the notions of derivative, of linear mapping, matrix, matrix computation in Mathematics and Chemical equations, Graph plotting in simple chemistry experiments, and description of relationship between pressure, temperature and volume as in Boyles law....).

To implement PBL in Mathematics and Sciences, we really want the students to acquire a new notion and not to limit their work to the "how to use it", which is the quite natural trend of most students. Most students are interested in corner-cutting and escaping with high scores in classroom assessment. This necessitates the need to be more directive for Maths problems than for PBL in other subjects. Thus it is discovered that giving the students a key-word to be properly studied and understood by each student may be a good way to guide the students without cutting initiatives.

We claim that most of what is known for building a PBL in applied subjects is valid for abstract ones (and particularly in mathematics and chemistry). However we must be more cautious so that the time spent by the student is essentially spent in mathematics (including oral and written expression), not in the applied domain (such as the production of an object). Quite often the corresponding work of the concrete object is, for math problems, computer results and for chemistry some empirical lab readings.

PBL examples in integrating knowledge in mathematics and chemistry

We consider here two examples to illustrate the need for integration of curricular for both math and chemistry. The first is applicable at the School curricula while the second addresses the University curricula.

Example One: Calculus in Chemistry

A PBL problem that was initiated in the Chemistry class on the topic of electricity (crossed circuits) would generally lead to various discussions

on :

- the definitions of energy,
- power and work
- and units of power.

This discussion can then continue in the Mathematics class with the introduction of Calculus through

- The use of rate of change of electrical energy in a household, rather than using the traditional method of using rate of change of displacement(speed) when introducing Calculus.
- The topic was further explored when learners had to plot a graph of electricity usage versus time, as well as interpret the graphical representation.

The outcome of this exercise is that the students would appreciate this integration of knowledge gained by themselves during the PBL tutorial sessions.

Example Two: PH-metrics modeling

This is a University Curricula example. This problem is presently used at Université de Toulouse, INSA, IMT(CR) as a Active Learning approach. Here we investigate the interrelationship between previous knowledge acquired in Chemistry and Mathematics as we look at the modeling discussion in a PBL tutorial session.

The problem

You are given various measurements of the neutralization of an acid by a base, and you need an evaluation of the position of the equilibrium point, which is, as you know, the inflexion point of the process. This evaluation must be entirely automatic, without any human intervention, so that it can be part of a larger automatic process.

How would you do to solve such a problem?

Of course, the data are "noisy", there may be measurement errors, influence of unknown parameters,...

However you are requested to characterize as precisely as possible this equilibrium point.

Four different approaches are to be examined successively:

1. Exact data, parametric model given ($\Rightarrow$ interpolation, choose significant data, stability)
2. Noisy data, parametric model given ($\Rightarrow$ approximation, least squares, nonlinear optimization)
3. Exact data, no model given a priori ($\Rightarrow$ interpolation of n data, cubic splines)
4. Noisy data, no model given a priori ($\Rightarrow$ least squares, smoothing spline)

Analysis

Context

Semi -realistic problem (student in lab), theme of the problem already known by the student (in a prior chemistry course).

Information

No real data given. The task is "conceptual" ("how would you do to...?")

Task

Effective learning issues: modeling, least squares fitting, interpolation and approximation by splines.

Obstacles

Difference between interpolation and approximation conceptual task.

As the students meet in the PBL tutorial sessions, during the brainstorming stage, there would be a recall of the previous knowledge of Numerical Analysis courses including interpolation, optimization, and other mathematical concepts.

RESULTS AND DISCUSSION

We present here the study to show that PBL in Mathematics and Chemistry is a means of integrating basic knowledge acquired from both subjects in order to proffer solutions to a well posed problem. The traditional way of formulating curriculum in an isolated manner can then be replaced with an integrated approach as seen in this work.

We want to emphasize here that there is no single model for a good problem, and various approaches are possible for deriving a mathematics or Chemistry problem suitable for a PBL setting. It is however necessary to complement PBL work by other ways to do mathematics, such as usual exercises, numerical experimentation (also possible, of course, within PBL), and to check that students do not share the work, especially that they grasped the generality of the studied abstract notions (but actually we can say that this last point is also true for traditional teaching).

We also want to emphasize the importance of analysing a problem from different angles (context, information given, task, obstacle...).

In order to keep a high student involvement and motivation, we have to make sure that the sequence of problems allows for varied situations, and so encourages discussions between the students. Of course, an a posteriori analysis of the sequence of problems is necessary to check that all objectives of the course (in terms of student competencies) are adequately covered.

Finally we claim that it is completely possible to construct problems in mathematics and to relate such to knowledge gained in Chemistry and vice-versa.

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