Abandoning Lectures in Favour of Active Learning

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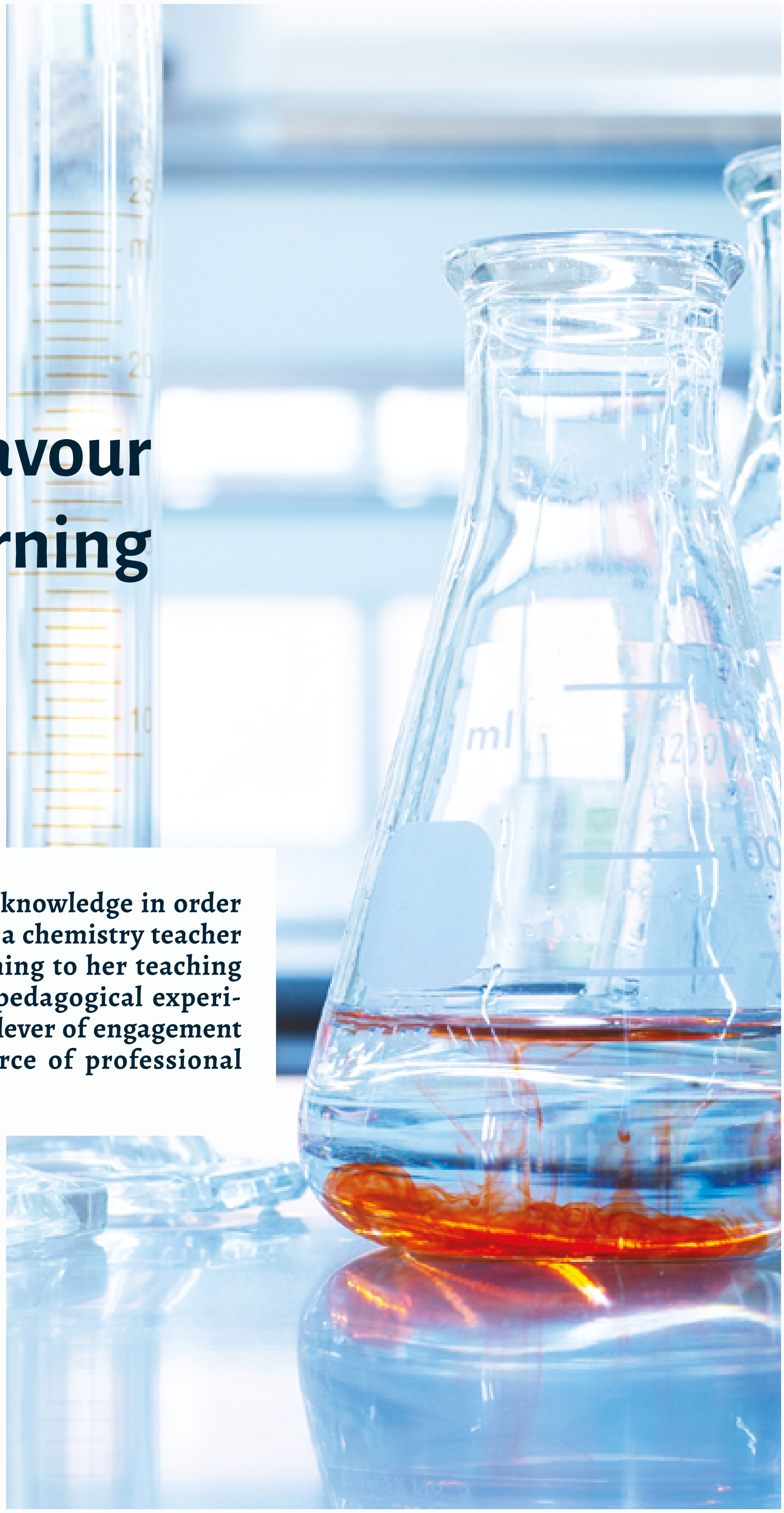
Giving meaning to pure science knowledge in order to engage students is the goal of a chemistry teacher who added problem-based learning to her teaching practice. This is the story of a pedagogical experience that has not only acted as a lever of engagement for learners, but also as a source of professional development for the practitioner.



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Lecturing remains the most common teaching strategy in pure science courses, in both pre-university and technical programs (Barbeau, 2007). I was tired of low student engagement, annoyed at seeing students dozing off during morning classes, bored with answering the question "What's the purpose of this?" and tired of listening to myself talk. Convinced that active learning strategies motivate students, I chose to add problem-based learning (PBL) to my professional practice. The strategy was greatly appreciated and certainly stimulated student engagement, which translated into student success on evaluations.

This article presents the problem I wished to address by integrating PBL into *Biomedical Chemistry I*, a technical program course. The choice of this strategy was validated both by my review of the literature and by the data I collected from students who experienced it. In between were conducted the planning, design, and implementation phases of the project, which are also documented in this text.

What is PBL?

PBL is an active learning strategy that takes place in different structured phases (see **Table 1**). The teacher takes on the position of a coach rather than a knowledge provider as they create a framework in which the student is active in solving an authentic and complex problem situation. The student collaborates with classmates. Together, they organize their research and exchange with each other in order to share the fruit of their research to solve the problem situation and, more broadly, to reflect on the learning constructed (CCDMD, n. d.).

An active strategy for the benefit of the individual

Since student empowerment is at the heart of PBL, the teacher abandons their role as a knowledge provider and becomes a guide instead. The student must solve the problem as autonomously as possible, because the primary goal of PBL is to solicit cognitive strategies from the student, to help them become aware of the solicitation of these strategies and to use cognition and metacognition (Bégin, 2008), which increases their motivation (Viau, 2009). This metacognition occurs as the student is invited to reflect on what they do, and this can be done before, during or after learning (Lauzon, 2014).

Active strategies such as PBL create a good perception of controllability for the student, since the achievement of the proposed goal depends on the student and the strategies they apply. When the student is presented with an activity that they can perform, the perception of competence is enhanced. These two perceptions are motivating factors (Viau, 2009).

PBL leads the student to plan, monitor and evaluate their learning autonomously. To do so, they must be faced with a well-defined, complex and authentic problem situation that is therefore stimulating (Ménard & St-Pierre, 2014). Holding only some relevant prior knowledge, the student uses it as a starting point and must seek more information that they will have to select, elaborate and organize (Barbeau, 2007). This leads to an analysis that stimulates cognitive and metacognitive processes, with the aim of responding to the problem situation.

Because the activity is conducted in teams, it is useful to assign roles to students. These roles vary among authors, as does the way PBL is segmented into steps (Ouellet & Brosseau, 2005; Ménard & St-Pierre, 2014). These steps are modulated according to the context of completion and need.

Similar to the benefits of the active strategies described earlier, when PBL was implemented in the Nursing program at the Cégep du Vieux Montréal, several positive outcomes were observed (Cossette, McClish & Ostiguy, 2004). Students felt more satisfaction with regard to the learning process when compared to traditional methods. Students' intrinsic motivation was improved, as well as their perception of general and specific competence in communication, teamwork, reflection and criticism. In a physics class at Cégep Limoilou, PBL was appreciated by students, who were more motivated and recognized better knowledge retention (Gaumont-Guay, 2013). While the success rate in evaluation is similar or slightly higher compared to traditional teaching, PBL allows learners to better retain learning in the long term and increase success in evaluations involving performance criteria, know-how, and attitudes (Strobel & van Barneveld, 2015).

Lecturing is a frequently used teaching strategy in pure science education. Several studies and articles (including Stains *et al.*, 2018; Marquis, 2014) attest to the prevalence of this teaching strategy. Yet, many also question the effectiveness of this teaching strategy (including Mazur cited by Bouffard, 2014; Dochy *et al.*, 2013; Martin & Padula, 2018). Regardless, the diversity of learning strategies is a motivating factor for the student (Viau, 2009), which may justify the integration of a new strategy, such as PBL.

My innovative project

The Master of Education degree offered under the umbrella of the Scholarship of Teaching and Learning (SoTL) approach allowed me to experiment with PBL in a researcher-practitioner position. My project aimed at integrating PBL into the *Biomedical Chemistry I* course in order to foster student engagement.

Planning and design

As a first step, I had to plan and design the project. To do this, I first chose the concept to cover, namely buffer solutions. This is a topic that integrates several pieces of knowledge acquired during the previous weeks of the course, and PBL precisely takes advantage of prior knowledge (Barbeau, 2007; Larue & Cossette, 2005). Thus, the activity took place at the end of the session. This strategic placement on the calendar has certain advantages. First, the students know each other at this point in the session, which facilitates teamwork. Moreover, other smaller-scale active strategies were implemented during the session, establishing a culture of active work and a gradual appropriation of technopedagogical tools. Finally, this positioning at the end of the session allows for the proper planning of the use of the various tools and the development of this segment of the course.

For the design of the didactic material, the contribution of a pedagogical counsellor is beneficial, and it was this counsellor who suggested that the class meetings take place in an active learning classroom (ALC). This type of room has several worktables, each equipped with a computer connected to a projector and adjoining a whiteboard. This is a great environment for brainstorming, an undeniable facet of PBL. However, it is important to note that a college does not need to have this type of facilities in order to implement PBL. The pedagogical materials projected or used online could have been handwritten or printed. However, a document sharing platform can be useful for file submission and collaborative work among students, allowing the teacher to keep an eye on the progress of the research during the individual data collection phase.

Implementation

Prior to the first meeting in the ALC, students were invited to watch a short video explaining what PBL is, its purpose, success factors, and how it works, as presented in **Table 1**.

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Table 1

PBL process

Phase	Step	Moment
Identification of the problem	• Setting the context • Knowledge of the problem situation • Clarification of concepts	1^{st} meeting (in an ALC)
Beginning of resolution	• Mobilization of prior knowledge • Issuing hypotheses	
Collection of information	• Individual collection	At home, between the first two meetings
	• Pooling of information collected and synthesis	2^{nd} meeting (in an ALC)
Validation	• Testing of hypotheses through experimentation	
Synthesis	• Solving the problem • Presenting the answer to the teacher	
	• Debriefing in class (summary lecture)	3^{rd} meeting (in a regular classroom)

Source: Adapted from Walsh (2005), Tremblay (2009) and Soukini and Fortier (1999)

At the beginning of the first meeting, teams of four or five members were formed. With the goal of empowering the students, a bank of self-assigned roles was proposed (see **Table 2**). Three roles (secretary, facilitator, spokesperson) were essential, while the others (workhorse, devil's advocate, time keeper, scribe) were distributed so that each team member could play a role. At the second meeting, the students were asked to change roles. In order for me to stay away from the posture of knowledge provider, a rule was established: only the spokesperson could question the teacher if the team was stuck, and the possible answers were "yes", "no", "it doesn't apply", or "it is not relevant." Although this instruction seems limiting at first, it was implemented in response to the observation that students made little attempt to hypothesize and quickly reverted to a passive position, which was counter-productive given the focus of PBL.

Table 2

Roles of team members

Roles	Task definition
Secretary	Notes comments and reflections on the documents.
Facilitator	Leads the discussion and stimulates exchanges.
Spokesperson	Interacts with the teacher if there is an impasse. At the end of the PBL experience, presents the team's reflections.
Workhorse	Ensures that out-of-class assignments are completed on schedule and addresses the offending team member as needed.
Devil's advocate	Challenges assumptions and thoughts submitted by other team members.
Time keeper	Controls the pace of work and discussion, monitors time and is responsible for scheduling tasks during and between meetings.
Scribe	Writes directly on the whiteboard, while the secretary then collates the relevant information into the templates.

Source: Freely adapted from Azer (2009) and Uden and Beaumont (2006).

Then, the steps to be completed during this first meeting as well as the expected tasks and associated documents were presented. When it is first ensured that the methods of completion and the expected tasks are well understood, the students' perception of competence is stimulated.

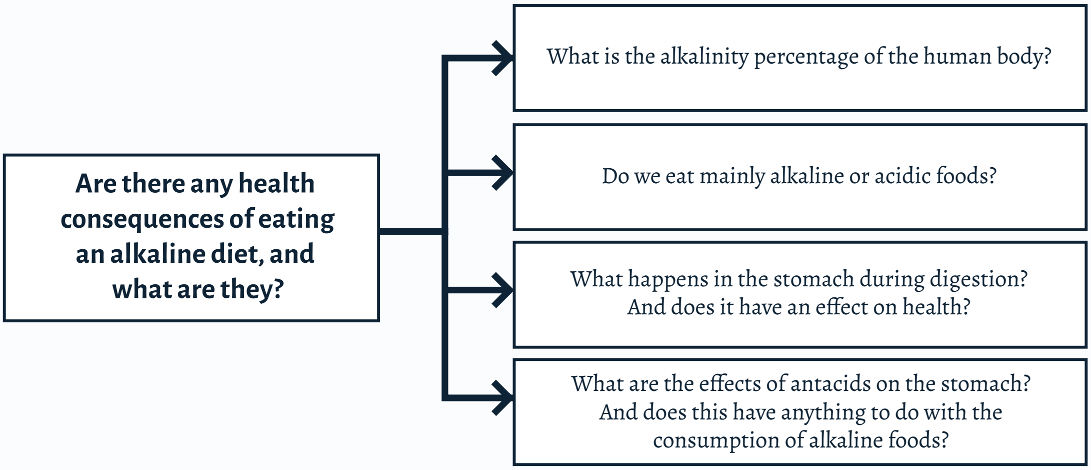
For context, each team was provided with a different article found on the Web. This variable context of realization provides individualization of the results obtained, increasing the perception of controllability and thus, engagement (Viau, 2009). These articles about alkaline diets with alleged benefits for the body—of poor quality, based on false premises and written by authors with a pecuniary interest—are often found on the first page of search engine results. It is then up to the students to note, because of their research and their perspective of the problem situation, that these articles are completely misleading.

The problem situation reads as follows: "Your cousin, a high school student interested in pursuing a science degree, approaches you to discuss the article you have read. Are the statements in the article true? Help your cousin form an opinion based on facts." The problem situation is well contextualized and challenges the student by situating them as an expert, since they already have knowledge on the subject, which again stimulates their perception of competence.

Various resources, such as templates, slide shows, virtual simulators and experiments, have been designed or identified to support the student. In the first meeting, the team uses the POPR template (for Problem – Organizational Chart – Prior Knowledge – Research), a template that team members and the teacher have access to. Inspired on Williams (2017), this document is used to rephrase the problem situation into a question to which a team response will be written after the second meeting. This question is divided into as many sub-questions as there are team members. **Figure 1** shows an example of a flow chart created by a team.

Figure 1

Organization chart created by a team of students



Far from being trivial, the creation of the flowchart is a critical metacognitive process, as the student sets a personal learning goal. Collaboratively, the team members list their relevant prior knowledge and decide on elements to pursue more in depth, which requires them to discern and assess their abilities in relation to the proposed learning. This metacognitive process continues as the student is called upon to conduct non-supervised individual research. Outside of class, students report their research in a shared document, which allows them to hypothesize the underlying question they have been assigned.

An opportunity to step outside the box

For their individual research, I was surprised to find that just over a third of the students had consulted references with little credibility and unsubstantiated information. As a result, some of them came up with a hypothesis that needed to be refuted. When they compared their data with that of their teammates, there was a clear disparity.

I saw this as an opportunity to discuss with them the evaluation of sources, the prioritization of online search results, and search engine bias. Although this aspect is not directly related to the content targeted by PBL, it does tie into the educational intent of the program regarding judgment skills. The discussion on this topic was so rich that I want to address the relevance of references more in other courses. In the age of social media and click bait, I feel it is important and necessary to explore these issues with pure science students. This is one of the strengths of active learning strategies: highlighting relevant related topics that engage students.

In the second meeting, the student synthesizes the data they have collected in order to present it to their teammates. Individual hypotheses are tested by pooling the information collected and by means of experiments using buffer solutions. This allows for the inclusion of procedural knowledge, which is important in pure science. This is followed by collectively writing a detailed solution to the problem, in a template provided for this purpose. In my project, all the teams came to the correct conclusion that the body regulates the pH of its various organs through many buffer systems and that an alkaline diet has no benefit.

After the second meeting, resources (readings and videos) were suggested to the students so that they could deepen their knowledge about buffer solutions. A self-assessment and a questionnaire were proposed to conclude their metacognitive process and to allow me to collect data to analyze the project. The PBL activity was concluded with a class debriefing, which is discussed later in the article under the limitations and drawbacks of the project.

Appreciation, engagement and metacognition

The questionnaire, consisting of approximately 40 questions, was distributed at the end of the course and was used to assess the appreciation of the PBL activity and the engagement it generated. **Table 3** presents the topic of the questions as well as a brief analysis of each.

Student engagement was also noted through the collection of factual data. Few absences as well as positive reports

Table 3

Summary of the questionnaire distributed to students

Question topic	Brief analysis[1]
Appreciation • Activity in general • Context of the activity • Desire to relive the PBL activity • Recognition of usefulness	The vast majority of students enjoyed the activity. The vast majority of them recognize that PBL is a better way to build long-term learning than lectures.
Involvement • Time spent on individual work • Rigour	A small minority of students report little involvement, justified by a lack of organization.
Cognition • Introspective reflection on skills and competencies • Introspective reflection on how to answer a scientific question for which one does not have the answer	The vast majority of students report reflecting on their abilities as learners, their self-perception, and their sense of competence.
Learning • Development of learning about the subject (buffer solutions) • Ability to recall learning in the medium term	All survey respondents feel that they understood the importance of buffer solutions to the human body. The vast majority of students consider that they will be able to apply this learning in the future.

Source: Freely adapted from Azer (2009) and Uden and Beaumont (2006).

[1] The ethical certification of the project imposes restraint on the disclosure of precise statistics.

Source: YinYang/iStock

of the number of online resources viewed stand out. While supervision was done to see if students were completing their portion of the individual data collection, only 2 out of 51 students had to be called to order. Many more students completed comprehensive research and verbalized that they spent a great deal of time on it out of personal interest, which means they were driven and engaged.

Integrating a new practice must be pleasant for the teacher. In a journal filled with my reflections and observations as the project unfolded, I noted that I was blown away by the students' engagement. The discussions that took place in class were rich and frequently continued after the meeting. This journal, filled with objective and subjective annotations, attests to my appreciation of the practice. I noted that "my profession takes on its full meaning."

Drawbacks and limitations

While I have a very positive assessment of this experience, I feel it is important to note some limitations of the project. First of all, absenteeism can be problematic during team work. Some students who were absent at the first meeting had to be contacted in order to join a team at the second meeting. I admit that this aspect was not considered at first and that I had to create a document at the last minute to send to the absentees so that they could make a meaningful contribution. The design stage of a new learning strategy, no matter how thorough, does not completely eliminate some surprises. PBL, which gives a great deal of autonomy to students, is certainly no exception.

Unaccustomed to active learning strategies, some students needed validation. "Have I understood correctly?" was a recurring question during the session. Several students asked to validate their acquired learning, which is an interesting metacognitive process. Faced with the extent of this need for students to validate their learning, I gave in to the temptation to offer a lecture to summarize the learning that had been or should have been consolidated. Drive off character, it comes back galloping!

This may seem to negate the whole PBL process. In retrospect, I see it as an inadequate way to get the students to question their learning. This impression seems to be validated as a majority of the students stated that this feedback validated their learning, and only a minority of them emphasized that it was this feedback that allowed them to understand. By encouraging them to compare what they had understood with what was presented and to try to understand why there was a difference, if any, I stimulated cognitive processes. In the second iteration, this validation

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would be done with exercises and tutorials rather than a lecture. The fact remains that PBL must conclude on a debriefing, which was done in a suboptimal manner in my project.

Benefits and areas for improvement

When one remembers that the primary goal of the SoTL process is the development of one's professional practice, the benefits to be considered are not only those concerning the students. My professional practice has certainly been enhanced by the planning, design, integration and analysis of a new learning strategy. This new strategy, despite the magnitude of the task, has been highly motivating and has fulfilled my need for renewal. Reflecting on my professional practice, I have changed the way I provide feedback, making greater demands on students' metacognition. I frequently include authentic contexts in my courses, and it is clear that this is often the segment that generates the most interest and questions.

The benefits to students are numerous. The objective of acquiring declarative and procedural knowledge about acidity and buffer solutions, one of the elements of the competency specified in the ministerial devis, has been achieved. This is validated by the clear success of an essay question devoted exclusively to this topic on the final course evaluation, where over 85% of my students scored at least 3.5 out of 5.

As an avenue for improvement, an additional meeting was planned to take place in a laboratory setting. The students would have conducted various experiments to produce and test buffer solutions. For personal reasons, this meeting could not take place. I suggested simplistic, but sufficient, experiments and the use of virtual simulators, which are useful and increasingly available for pure science. The students would have been even more engaged in their learning if they could have further validated their hypotheses with various experiments. They will certainly be part of the second iteration of my project. Almost all of the students appreciated the proposed experimentation; half of them considered it necessary for their understanding, while the other half saw it as a way to validate their learning.

Also, in order to further promote metacognition, I would question the students more formally during the activity to encourage this reflective process. It would be interesting to ask them how they intend to accomplish certain tasks, what difficulties they anticipate, etc.

Conclusion

The goal of my innovation project was to integrate PBL into the *Biomedical Chemistry I* course to foster student engagement. To achieve this, a stimulating context of realization was established. A high level of autonomy given to students to increase their perceptions of competence and controllability in a well-structured activity also contributed to the achievement of the objective. When questioned, a great majority of students expressed appreciation and engagement, which was evident throughout the project. Since the purpose of any learning strategy is to make students learn, it is relevant to note that the content targeted by PBL was grasped by the students. It is not enough for a strategy to be cool, new, or different; it must, first and foremost, help each student learn.

Certainly, adopting a new learning strategy requires an investment on the part of the teacher, possibly more than when preparing a lecture. The work is highly rewarded by the stimulating exchanges, the engagement of the students, and the realization that all of this leads them in the right direction. ▬

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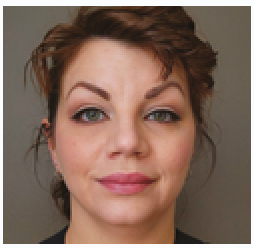

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