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Predictors of Student's Engagement and Persistence in an Innovative PBL Curriculum: Applications for Engineering Education*

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The objective of this paper is to present the overall results of a study focusing on the engagement and persistence of undergraduate students in two PBL engineering curricula (Electrical Engineering and Computer Engineering) at the Université de Sherbrooke in Canada. We will also discuss the results in terms of applications for engineering education. There were 192 undergraduate engineering students who volunteered to participate in this study. First, they completed a questionnaire to measure the best predictors of students' engagement and persistence in their respective programs. Second, we met with 15 students who volunteered to participate in interviews. Results from the questionnaire show that the best predictor in both programs regarding students' engagement and persistence is the provided 'support,' which reduces stress. Results from the interviews reveal that the support most effective for students proves to be the stable learning environment (PBL tutoring sessions) as well as the scaffolding measures for managing time and organizing learning practices. Taking into consideration the results from both the questionnaire and the interviews, it appears essential to limit these risks by taking measures that will reduce stress factors and increase strong support.

Keywords: problem-based learning; project-based learning; engagement; persistence; innovation; engineering education

1. INTRODUCTION

AT THE CENTER for Research in Higher Education†, the goal of our research program is to assess the impacts of innovative curricula, of which Problem—Based and Project—Based Learning (PBL) curricula are instances, on students and teachers‡. The objective of this paper is to presents the overall results of a study looking at undergraduate students' engagement and persistence in two PBL engineering curricula (Electrical Engineering and Computer Engineering) at the Université de Sherbrooke, Canada. We will also describe the applications the results may have for engineering education.

In order to do so, we will first explain how we based our work on the concept of 'curriculum' and briefly discuss the limited literature on 'curriculum design'. We will then argue over the need to take a curricular perspective with reference to engineering education, especially in the context of innovative pedagogical changes. When considering pedagogical innovation, there is a need to rely on a formal conceptual framework defining it. From this perspective, we will consider students' engagement and persistence in the two PBL curricula we examined. We will first present the methodology we have developed in relation to the theoretical background as well as the research context. Then, we will present the overall results obtained, derived both from a questionnaire and interviews. Finally, we will discuss the potential applications for engineering education.

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† In French: Centre d'études et de recherche en enseignement supérieur (CERES).

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2. DESIGNING THE CURRICULUM

The concept of a 'curriculum' is not often used in higher education [1], but it offers a framework from which to rethink the way teaching and learning are taking place. One may look at the curriculum from a structural point of view, but it is also important to considerer at least three other views: values, process, and content. Indeed, each of them helps better define the curriculum: the interrelations between its components; the core values (sometimes ideologies) around which it is built and developed; the phases through which the change process will go; and finally, the knowledge that students are expected to acquire, as well as its place and its meaning.

Few articles tackle the issue of curriculum design in higher education and its impacts. Some articles have looked at the impacts of curricular changes when modest changes were made (e.g., [2]) or different forms of knowledge students build (e.g., [3]). Walkington [4] has attempted to take a more theoretical perspective on the process of curriculum change in engineering education. He proposes four interrelated stages derived from a case in engineering: (1) the proposition for the new curriculum emanates from a small group of colleagues; (2) it is discussed with department and faculty members; (3) it goes through a design and development stage and finally, (4) it reaches its implementation phase.

One of the most well-known cases of curriculum change in higher education refers to the implementation of Problem-based learning (PBL), mainly in the field of medicine [5–7]. This curriculum change was first put forward at McMaster University in the late 1960s, but since then, it has been implemented in many universities and professional fields [8–10].

One of Barrows' most recent definitions [11] identified the following key components of PBL: (1) Ill-structured problems are presented as unresolved so that students will generate not only multiple thoughts about the cause of the problem, but multiple thoughts on how to solve it. (2) A student-centered approach in which students determine what they need to learn. It is up to the learners to derive the key issues of the problems they face, define their knowledge gaps, and pursue and acquire the missing knowledge. (3) Teachers act as facilitators and tutors, asking students the kinds of meta-cognitive questions they want students to ask themselves. In subsequent sessions, guidance is faded. (4) Authenticity forms the basis of problem selection, embodied by alignment to professional or 'real world' practice.

Such distinct curricular choices could be considered innovative, even today where lectures remain the dominant mode of teaching in higher education [12]. But what would an 'innovative curriculum' refer to? This is what the next section will attempt to explain.

3. INNOVATIVE CURRICULUM

The concept of innovation was introduced in economical and entrepreneurial domains, as one may witness from numerous studies conducted on this topic (e.g., [13]). It is therefore not surprising that it eventually appeared in higher education institutions, especially in North America [12]. Based on a literature review and prior work that took place at the Research Centre in Higher Education at the Université de Sherbrooke, we were in a better position to identify the characteristics of an innovative curriculum. Table 1 presents the framework that encompasses these elements. These characteristics help us define each curriculum and describe the similarities and differences.

Table 1. Characteristics of an innovative curriculum [14]

	Characteristics
Innovative curriculum	1. Student-centered teaching and learning. 2. Contextualization of teaching and learning. 3. Evaluation coherent with the spirit of innovation. 4. Curricular emphasis on the transfer of learning. 5. Reduction of 'disciplinary. compartmentalization'. 6. Collegiality between professors.

Problem- and Project-BL curricula are special cases in this higher-order category.

Lachiver and Dalle [15], as well as Van Driel, Verloop, Van Werven and Dekkers [16] mention that such innovative programs tend to propose student-centered teaching. These curricula also put forth the idea that such programs should stress the 'contextualization of learning and teaching' [17], especially as it relates to the profession. Van Driel et al. [16] as well as Tardif [18] make note of the fact that, in an innovative curriculum, the evaluation process taking place is coherent with the orientation of the innovation, e.g. 'learning by doing' would command a process that requires students to demonstrate their learning through activities, such as projects. Not only is the evaluation process aligned with the values and principles of the innovation, but innovative curricula also put emphasis on the transfer of learning [19], therefore stressing their concern with the ways students will make use of the knowledge and skills acquired in higher education institutions. Another characteristic of innovative programs refers to their intention and measures put forth to contribute to the reduction of 'disciplinary compartmentalization' [20–22]. Last but not least, Béchard [23] noted the presence of collegiality among professors, as well as a tendency to share their pedagogical expertise.

A curriculum may be described as 'innovative' when most of these elements characterize this curriculum. The learning path that it proposes will typically challenge most students admitted in higher education, as it is surely the case of students enrolled in two innovative engineering curricula in computer and electrical engineering at the Université de Sherbrooke have implemented PBL. The next section will present their characteristics. A more detailed description of how these curricula relate to the conceptualization of innovative curriculum can be found in Bédard, Lison, Boutin, Côté, Dalle and Lefebvre [24].

4. ENGINEERING EDUCATION FROM A CURRICULAR PERSPECTIVE

In 2001, the Department of Electrical and Computer Engineering of the Université de Sherbrooke has implemented two revised curricula.

After reviewing both the state of their Bachelor of Engineering degrees and the literature on learning and teaching in higher education, it was decided to adopt a new learning and teaching paradigm, which would lead students and professors away from the more common lecture mode encountered in most engineering education practices [25].

To describe the Electrical Engineering Curriculum (EEC) and Computer Engineering Curriculum (CEC), we will refer to both the six characteristics of an innovative curriculum and the four views mentioned above: values, process, structure, and content. Since both curricula have been designed simultaneously and that they share a certain number of activities, especially in the first year, the following description will apply to both.

This shift was based on two founding frameworks or *values*: competency-based education and 'constructivist philosophy' of teaching and learning. Typically, in a competency-driven curriculum competencies are designed as final outcomes and built-in as intermediary targets along the semesters of curriculum. 'The learning framework is based on fundamental principles suitable to competency-based education' [26, p. 22]. This implies that attention has been given to the impact of prior knowledge, the importance of knowledge organization in relation to professional contexts, and the transfer of knowledge supported by direct actions. The constructivist philosophy of teaching and learning situates both activities in a different rapport than what is typically known in higher education. It essentially refers to the idea that the curriculum should be 'learner-centered', i.e. there should be a paradigm shift from teaching to learning.

Barr and Tagg [27] call the traditional, dominant paradigm the 'Instruction Paradigm'. Under it, teaching is conceived mainly as delivering lectures, and institutions as delivering instruction. The shift to a 'Learning Paradigm' implies that a curriculum's end should not be its means (teaching), but 'that of producing *learning* with every student by whatever means work best' [27, p. 697]. In both the EEC and CEC curricula, this meant to question the usual teaching practices. These values illustrate the place given in these curricula to a 'student-centered teaching and learning' environment, to the 'contextualization of teaching and learning' and to the 'transfer of learning', all three characteristics of an innovative curriculum.

The *process* by which these values helped design the two competency-based curricula was 'top-down'. First, professional competencies were identified. Second, a curriculum map was designed, distributing each competence throughout the curriculum. Third, specific activities aimed at facilitating the acquisition of knowledge and skills and, ultimately, the development of competencies were developed. The adoption of the new learning and teaching principles also had an effect on the process. As Lachiver et al. [26] state, at that point, 'it appeared almost impossible to preserve a curriculum that gave priority to quite distinct activities such as lectures and laboratories, which stress adding knowledge rather than integrating it into competencies' (p. 22). The process also involved the participation of professors from both programs and their collaboration in developing the material to be used. In doing so, the directors of both curricula have established early on a spirit of collegiality amongst the professors. This last characteristic of an innovative curriculum remains one of the most important challenges facing departments who choose to change their curriculum, especially in light of the arrival of new members of the department over time [28].

The *structure* of the new Electrical Engineering Curriculum (EEC) and Computer Engineering Curriculum (CEC) was drastically different than before. Before the change took place, students were asked to engage each week in five different three-credit courses, for 15 weeks. Typically, each course implied a weekly schedule of three hours of lectures, three hours of laboratory or exercises and three hours of study. The choices that were made gave birth to what can be called a Problem-Based and Project-Based Learning (PPBL) curriculum in engineering. Figure 1 shows how a typical semester is structured in the new curricula. The number of PBL units may slightly vary from one semester to the next. At the same time, students are asked to realize a design project that 'provides an authentic engineering environment [to apply what they learn in PBL Units] and promotes 'real-world' skills intended to stimulate professional situations' [26, p. 23].

Both problems and projects are aimed at contributing to the development of competencies, which in turn should guide knowledge or *content* acquisition. Inversely, in both these competency-driven curricula, knowledge is looked at as tools used to build competencies. The resulting learning and teaching context helps prevent knowledge fragmentation or compartmentalization, while providing an environment that fosters 'the process of personal and social construction of knowledge' [26, p. 21]. It is clear in Fig. 1 that the 'reduction of disciplinary compartmentalization' (fifth characteristic) was a important part of the curricular changes made. Indeed, all problems submitted to students are multidisciplinary in nature. The evaluation measures proposed have taken into

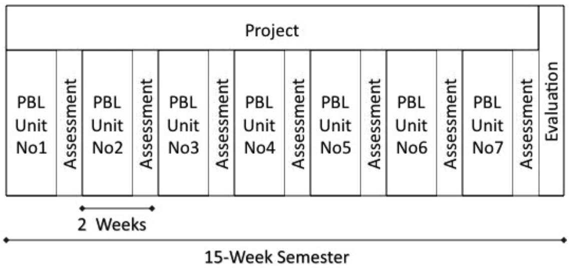

Fig. 1. Structure of a 15-week semester in the PPBL curriculum in EE and CE at the Université de Sherbrooke.

consideration the changes that were made, but the coherence between these measures and the spirit of the innovation (third characteristic of an innovative curriculum) remains a challenge to be fully met, especially as it relates to the evaluation of competencies.

As one may recognize, the changes that were implemented in the Electrical Engineering (EE) and Computer Engineering (CE) programs have been important. Moreover, these changes were orchestrated in view of each engineering program as a 'curriculum'. In sum, the values promoted throughout the curriculum emphasize the importance of the integration of knowledge, learning by doing, and student-centered teaching. From the first term to the last, the acquisition of knowledge and skills represents building blocs aimed at developing competencies. Finally, the change process from which these two curricula were conceived and implemented initially involved a leading group of individuals. They laid the conceptual and structural foundations on which professors from each program built their capabilities to engage in the change process that was proposed.

From a more pedagogical point of view, these curricula changed the ways teaching and learning have taken place. It may be said that professors involved in these changes innovated by attempting to improve the way students learn to become engineers, the end results being an 'innovative curriculum.' Among the factors affected by such important changes at the curricular level is students' engagement and persistence. This is what we will bring into focus in the following section.

5. PREDICTORS OF STUDENTS' ENGAGEMENT AND PERSISTENCE

Questions related to students' engagement and persistence are not new to the field of education. What is new in the approach to these issues is the curricular perspective from which we address them. Typically, researchers have considered specific tasks or activities when trying to predict or explain these two manifestations, e.g. perform a task, pass an exam, solve a problem [29–31]. Our research perspective aims at identifying the factors that best predict students' engagement and persistence at the 'curricular level,' more specifically with innovative types of curricula.

From this perspective, we conducted a literature review to identify the factors addressed by researchers and developers, which pertained to students' engagement and persistence within the innovative curriculum. The results will now be presented. An initial model presented six categories of predictors. After the first analysis, four main dimensions remained (see Fig. 2). These dimensions are divided into nine predictors. The following paragraphs describe each of them.

Bandura [32] has studied the concept of **self-efficacy**. His research has shown that the more individuals perceive their own actions as effective, the more likely they will persist in the task they are doing in terms of time and efforts invested. When the opposite is true, individuals will be likely to disengage their efforts and avoid using strategies and knowledge they have already mastered, therefore generating a feeling of anxiety. According to Bandura [33], self-efficacy can be defined as the judgement one makes on his/her capability to exhibit a series of specific behaviours for the purpose of reaching a certain level of achievement. Such judgement stems from gathered information from which an individual will initiate his/her actions.

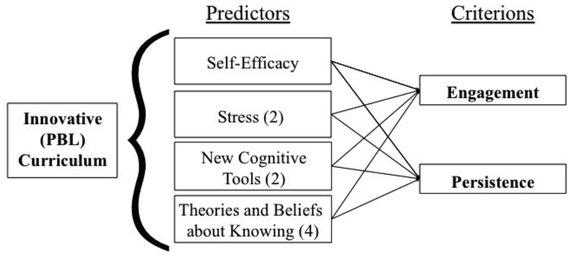

Fig. 2. Predictive model of students' engagement and persistence in an innovative curriculum.

The notion of **stress** has attracted much attention since the 1960s. It is now common knowledge that 'perceived stress' is more likely to reveal one's own level of stress [34]. Indeed, the impact of a *stressful environment* on an individual is filtered by his/her perceptions of that environment, therefore varying the degree of importance. This vision implies that people interact actively with their environment and appreciate potentially stressing events in light of personal and contextual resources [35]. Stress can therefore be conceptualized as the particular relation between individuals and their environment as events in the latter exceed the resources available to them, therefore threatening their well being [36].

Mostly studied in relation to people's personal environment, stress has also been examined in the workplace [37]. Indeed, **stress at work** represents well what students experience when considering the many curricular activities they are faced with during their undergraduate studies. Indeed, the learning path that students are asked to engage in during their years in higher education can be a stressful experience. There is a growing appreciation of the stresses students may experience during those years, especially in medical education [38–40]. As a result, there are factors in the learning environment that contribute to stress (perceived stress) and others that hinder its appearance (perceived support). In the present paper, the factors contributing to stress will be called 'stressors', whereas the factors limiting or inhibiting stress will be called 'supports'. We have considered both as predictors of students' engagement and persistence in their curriculum.

One of the issues raised by the presence of innovative curricula relates to finding out whether the students' ways of learning and studying were affected or modified. Typically, the introduction of such innovations is driven by the want of students engaging differently in the curriculum, at least from a pedagogical point of view, e.g. learning by doing or working cooperatively [17]. Such learning environments require students to rely on '**new cognitive tools**.' The literature points towards two of those cognitive tools: *knowledge articulation* [41] and *reflexive thinking* [41, 42]. Knowledge articulation refers mainly to students' capacity to distinguish knowledge and strategies applicable to a specific task [43]. According to McLellan [42]: 'By articulating thinking and problem-solving processes, students come to a better understanding of their thinking processes, and they are better able to explain things to themselves and to others.' (p. 12). As for the ability to reflect on one's thinking process, Lajoie and Dery [44] mention, 'the specific importance of reflection is its role in consolidating the development of new strategies.' (p. 322). As it is often expected in a PBL environment, reflexive thinking should be part of students' strategies because it 'enables students to compare their own problem-solving processes with those of an expert, another student, and ultimately, an internal cognitive model of expertise.' [41, p. 482]. Students' ability to rely on those two cognitive tools should allow predicting their engagement and persistence in the curriculum.

Each individual has epistemological **theories and beliefs about knowing**. In this respect, these theories and beliefs allow one to make sense of the knowledge that he/she acquires, both as an individual and through collective learning situations, e.g. PBL units [45, 46]. Within this broad scope, we have focused on the work of Perry [47, 48] and that of Bédard, Frenay, Turgeon and Paquay [49]. Perry [47, 48] has proposed a developmental scheme to help explain students' cognitive development throughout their undergraduate years.

The different levels he puts forward may be grouped in three stages: *dualism*, *subjectivism* and *relativism* [50–52]. At the 'dualist stage,' students' perspective on knowledge is dualistic: right or wrong. Problem solving activities will serve as opportunities to learn the right (expected) answer. At the 'subjectivist stage,' students add a perspective on knowledge that shifts to 'personal truths'. The '*I think or believe that . . .*' tinges with discussions. When adopting this posture, students see solving problems as a means to finding out the solution on their own. Finally, at the relativist stage, knowing is interpreted through 'contextual lenses'; truth becomes context-dependent. It refers to the '*It depends . . .*' stage. Solving problems is therefore seen as a means to interpret and situate knowledge in light of contextual information or available data. Perry's work, though prior to most 'innovative curricula' known today, appears very useful to analyse students' posture towards knowledge as was presented in PBL learning environments through problems within a context.

This last observation leads us to consider students' perceptions of knowledge, which pertains to the context in which it is presented or processed in PBL. Bédard et al. [49] have attached importance to this factor in terms of promoting students' capabilities to transfer knowledge acquired in the curriculum to extracurricular situations found in the workplace. Based on Viau, Joly and Bédard's [53] findings, we believe that the importance attributed to the 'contextualization of knowledge' should help predict students' engagement and persistence in a curriculum that introduces it as one of its main characteristics. It represents the fourth dimension of the category **theories and beliefs about knowing**.

To complete this section, we will define the two manifestations (criterions) we are attempting to predict, namely **engagement** and **persistence**. Students' engagement is typically defined as the time they invest while taking part in a learning activity. Pirot and De Ketele [31] add that it also involves students' affective, cognitive, and metacognitive mobilization. Therefore, to be engaging in learning tasks (academic engagement) or in a curriculum (curricular engagement) implies that one will devote time and effort while participating in the prescribed activities. Pintrinch and Schunk [30] define persistence as the conscious choice one makes to carry on with an activity despite the obstacles or difficulties he/she may encounter. To summarize, when students' engagement refers to putting forth the efforts requested or needed to succeed and their persistence becomes a measure of their capabilities to face and overcome potential obstacles along the way.

6. RESEARCH QUESTION AND METHODOLOGY

Our research question was: Which variables better predict students' engagement and persistence in innovative curricula, such as problem-BL and project-BL? Accordingly, two hypotheses were formulated:

H1: The four dimensions, dividing up into 9 variables, will all predict students' engagement, apart from the curriculum.

H2: The four dimensions, dividing up into 9 variables, will all predict students' persistence, apart from the curriculum.

6.1 Subjects

During the 2006–2007 academic year, 192 undergraduate students from all four years of the two programs aforementioned completed a questionnaire to measure the best predictors of students' engagement and persistence in their program. Of that overall number, 56% were from the Electrical Engineering program and 10% were women. We may add that 90% of the subjects were Caucasian and 73% had done an internship in their field prior to participating in the research.

Of that group, we met with 15 students who volunteered to participate in interviews. These interviews were planned to get an in depth look at the factors investigated in the questionnaire. Nine students were from the Electrical Engineering program and two participants were women.

6.2 Data collection and analysis

Present knowledge on methodological issues in educational research invited us to transcend the traditional categorisation between quantitative methodology and qualitative methodology. Some argue that the adoption of mixed methodologies is better suited to the complexity of pedagogical issues [54, 55], especially concerning innovative educational approaches [14].

Our research has adopted mixed methodologies to tackle the questions being raised here. Two methods of generating data were applied and devised: (1) a self-reported questionnaire and (2) interviews with focus groups. The questionnaire was formulated in order to have access to students' perceptions about their learning experience in their PBL curriculum. The interviews conducted in focus groups were aimed at getting more in depth data on these experiences. Our initial aim was to meet with 5% to 10% of the subjects from the sample. Participation was voluntarily in both collections of data.

In order to investigate the four dimensions (predictors) and two factors (criterions), we developed a survey that contained 95 items at the end of the three-step validation process: content analysis (5 experts), construct analysis (10 students), and item analysis (102 students). The last analysis allowed us to calculate the internal consistency reliability for each statement (items) using Cronbach's alpha statistics. Items having scored above 0.70 were retained [56]. Normality was checked for all variables. The average time it took students to complete the questionnaire was 20 minutes.

Following this first step, we designed a series of semi-structured questions to complete the information gathered through the survey. These questions addressed all of the above-mentioned dimensions and factors. We agreed on meeting with the subjects in small groups of 4 or 5 students. This method originates from the focus groups' methodology. It allows the students to share their experiences and witness those of others. Moreover, it allows us to collect more information from students. Overall, the interview process lasted between 60 and 90 minutes.

The data from the questionnaire were entered and analyzed using the Statistical Package for Social Sciences (SPSS), version 12.0. For both hypotheses, the data was analysed using a regression analysis, Stepwise Selection, to identify the best predictors for each of the two factors (criterions). A p-value < 0.05 was considered statistically significant.

The data from the interviews were first analysed in conformity with the procedure prescribed by Miles and Huberman [57], i.e. raw data were transcribed and compiled in software called N-Vivo. They were then divided up into meaningful units or themes in order to facilitate their analysis. We first established large but flexible categories in order to facilitate the interpretation of the data. Afterwards, we compared this data to the one gathered with the questionnaire.

The mixed methodologies we used gave us a rather complete picture of students' perceptions and learning experiences in their respective curriculum. We made these choices in the hopes that students would reveal additional data, thus allowing us to verify the value of the predictive model initially proposed.

7. RESULTS AND INTERPRETATION

7.1 Results from the questionnaire

Some of the results in relation to both hypotheses have been presented elsewhere [24, 58]. Both of these papers essentially emphasize the more theoretical and conceptual implications of the results obtain from the questionnaire for the study of engagement and persistence in higher education. In this paper, we will first present the overall variables that best predict engagement and persistence for both curricula, but we will mostly present and discuss new results derived from the interviews done with students. Indeed, students' comments and answers to our open-ended questions (semi-directed interview) will allow us to reflect on the curricular design and choices that were made in the two PPBL curricula investigated here. An overall discussion of the applications these results may have for engineering education will be presented in the conclusion.

When considering subjects from both curricula, the first hypothesis was not confirmed as such (H1). Indeed, the three variables that best predicted students' engagement are presented in Table 2.

Table 3 shows the three variables that best

Table 2. Best three predictors of students' engagement

Predictors	Criterion
1. Supports in the curricula (stress) 2. Contextualization (T. and B. about K.) 3. Reflexive thinking (new cognitive tools)	Engagement

Table 3. Best three predictors of students' persistence

Predictors	Criterion
1. Supports in the curricula (stress) 2. Knowledge articulation (new cognitive tools) 3. Stressors in the curricula (stress)	Persistence

Table 4. Statements in the questionnaire related to the stress predictors in the environment

Stress	**Supports**
	1. I get along with other students.
	2. Group work stimulates me.
	3. I like my studies programme.
	4. I respect most of my tutors and trust them.
	5. I get all the information I need for my studies.
	6. Within the framework of my programme, my tutor and teammates show me respect.
	7. My studies offer me a potential for personal growth.
	8. People notice the quality of my work.
	9. My studies allow me to display my skills and aptitudes.
	10. My schedule at the university corresponds to my needs.
	Stressors
	1. I am incapable of getting the necessary resources (information, support) to resume my activities at the university.
	2. I am confronted with vague expectations.
	3. I have restrictive deadlines.
	4. I perform tedious and routine tasks.
	5. I do not enjoy my studies.
	6. My studies do not allow me to display my skills and aptitudes.
	7. It is impossible for me to show creativity or initiative.
	8. I do not get what I was expecting or hoping for out of my programme.
	9. I feel indifferent towards my studies.
	10. I have misunderstandings with my peers and tutor.

predict students' persistence (H2). Again, the second hypothesis was not confirmed fully.

It is important to note the prominent place that the 'Support Factors' have in predicting both factors. In order to better understand how the measure of both supports and stressors was done in the survey, Table 4 presents the 20 statements related to this predictor: 10 for the supports and 10 for the stressors. Students had to indicate the level of agreement on a five-point Likert-type scale (5 = totally agree; 4 = agree; 3 = more or less agree; 2 = disagree; 1 = totally disagree).

Also of academic interest, it is important to note that variables predicting students' engagement explain a larger portion of the variance (63%) than it is the case for students' persistence (43%). Finally, some of the variables, which were supposed to play an important part in predicting both factors (e.g., students' perceived self-efficacy), do not appear to contribute significantly to the variance of either factor. The results were a surprise to everyone considering the importance some authors have attached to these variables in their explanatory models of students' persistence in relation to specific tasks (e.g., [32, 33, 59]).

7.2 Results from the interviews

Based on the group interviews, it is clear that, in both programs, much more stress is generated during the first year, but this stress is reduced in the following years. According to students' statements, there are at least two reasons for this: the new learning environment and the lack of appropriate learning strategies within this new learning environment [60]. Here are some statements that illustrates this situation:

> Going from an incredibly supervised environment to a confusing one is a major change. It's a big step, but we adjusted for sure. We began to understand where to invest our time and stopped wasting it.
>
> I don't believe our workload is heavy; it's just that we are not efficient. We work a lot before realizing we're not doing the right thing. There is a lot of trial and error. Logically, we should study before doing the work, but I think there are a lot of lazy people. In fact, that's my problem.
>
> I think it's also an organizational challenge. You're not structured like classes are. If you organize your time, you will have more than enough to do everything . . .
>
> The thing that reduces my stress is my PBL experience, knowing that I had already done 12 or 14 PBL tutorials and that roughly, it will come down to the same thing . . . You have to have confidence in your methods and know that you will get through it.

More specifically, students reported that their learning difficulties came from reading. They found it troublesome that, all of a sudden, they went from attending lectures as a learning method (where most of the information was provided for them), to attending PBL tutorials and engaging in self-directed learning where they are expected to acquire knowledge by reading. Invited to learn on their own, they must search for the pertinent information in relation to the problems presented, in a limited amount of time (2 weeks). Learning strategies such as the capacity to be organized become tools to reduce this stress factor.

> To be organized is essential to succeed in a PBL tutorial, that's for sure. Apart from that, you have to be assiduous. You have to do your readings and take notes so that your time will be worth something. If you read your book incorrectly and you don't remember anything, then it's time wasted.
>
> At first, I always did my readings. Then, I realized that I changed my way of reading, that I took another approach to revising, to rereading at the right moment. The way I plan my week has changed considerably compared to the beginning.

Specific transitory help known as scaffolding must therefore be provided for them [11, 17]. For example, in both programs, students are not compelled to find the information on their own to resolve the submitted problems. For each PBL unit, a student guide is there to help them discover, among other things, the learning objectives and consequently, the items that will be evaluated, the references recommended, and the chapters to be read. Furthermore, when necessary, complementary notes are posted on the website for that semester, thus offering more explanations concerning certain difficult reading sections in the recommended books. Though these methods may be somehow considered an 'erosion' from the original PBL model [10], they appeared important measures to take in order to alleviate students' perceived stress. Moreover, during the tutorial meetings, the tutor not only observes and validates, but also frequently leads the students to progress as they are expected to within the allotted time.

> Tutors have control over the subject matter. They would arrive with their big binder, ready for any question. They were structured; it was in a logical order.

> In the second part of the first tutorial meeting, it is interesting when he [the tutor] starts explaining things [. . .] sometimes, he'll drop a hint about the problem.

In spite of this assistance, students are still having trouble separating the items of importance from those of secondary importance in their readings [60]. To assist them further, 'concepts maps' (diagrams) have been introduced as a means to help them synthesize their readings. Information on the usefulness of diagrams and several examples are provided to students. In each PBL unit, students are encouraged to draw a diagram of their readings on a question given by the student guide and to submit it to their tutor. Students receive feedback on their diagrams, but no grades are given. Unfortunately, many students do not see the usefulness of diagrams.

From their standpoint, this new learning tool takes too much time to implement when considering the limited time they have to master the subject, especially if they are applying inappropriate learning strategies. This situation contributes to a high level of stress: too much time wasted applying inappropriate learning strategies and not enough time remaining to adopt new learning strategies. They should see the long-term benefit that can reap from initially investing time to adopt a new learning tool.

> It takes a lot of time to draw . . . However, it is useful to have one [diagram].

> We drew a few diagrams during our first year, barely . . . We were corrected. They hadn't been done properly. We all learned our lesson. Hardly anybody drew any more of these diagrams.

> Drawing diagrams is a good thing . . . There's a big difference between that and saying that each student is capable of drawing a diagram.

In between the two PBL meetings (tutorial), a few specific activities (procedural meetings and laboratories) have been developed to enforce the scaffolding of procedural and practical knowledge [24, 26].

During these activities, students work collaboratively on carefully selected exercises that stress on critical procedural learning. This complementary type of activity that has been added to the PBL process was judged to be required in engineering. It represents an innovative aspect of both curricula and a perceived support in the learning environment.

> From the first procedural meeting, we make progress in solving the problem.

> When the professor goes to the blackboard, everything goes well because he knows what he is doing.

Formative evaluation is another type of scaffolding that is put forward to help students in learning to assess themselves and therefore, reduces stress. After the closing tutorial meeting, a formative evaluation is posted on Internet along with the solutions. This formative evaluation gives students the opportunity to have a good idea of their level of learning that their tutors expect from them regarding essential concepts covered in the PBL units.

> Formative evaluation really reduces stress for the evaluations.

> Every Wednesday, before the exam, there's a formative evaluation. I think it's awesome! It gives you a good idea of whether you have understood the subject matter or not.

Students in the group interviews also attach considerable importance to collaborative work [25] in terms of learning and reducing stress [61]. Most students recognize that, without the help of other students, it would be much more difficult for them to succeed within the allotted time for each PBL unit. Very often, they share information and explain to each other sections of the subject in hand. Asking their tutor for an explanation remains a last resort for them. Collaboration rather than competition is encouraged, that is to say that criterion-referenced interpretation of student assessment performance [62] is made rather than normative assessment. When criteria are used to assess students' performance, they all have the opportunity of getting the highest grade as long as they reach the level of competency established in the programs and this, apart from the performance of others.

> Everybody helps each other. If you have a problem, people will take the time to explain it to you. It's great in terms of group atmosphere. I think it is more relevant to have that than to compete against each other because, in the labour market, that's how it's going to be. If you haven't developed that ability to explain what you have understood, then maybe the rest of your group won't understand where you're going, even if it's really touchy.

> Helping one another reduces stress in a way because if you are explaining an element to someone and you know that, concerning that element, the question will be exactly the same in the exam, that you were able to explain it to him, then you will be able to explain it on a sheet of paper . . . Helping others is always a bonus for me.

However, in the case of term projects carried out during PBL units, the team members occasionally come into conflict with each other, which can stressful. In this way, working in teams, usually taken as a support in the learning environment, can become a stressor as well when considered in a specific context, i.e. project team.

> It's really the project that stresses me the most. I'm usually the one who will start working before the others and who will finish on time. If I'm part of a team in which I'm the only one to be like that, then I feel bad because I'm under the impression that I have to motivate the team to finish on time and avoid botching the project.

Another point that was discussed during the interviews refers to students requiring feedback quickly from tutors on their work. Although this should be mandatory for any type of curriculum, it is especially true for PBL programs in which each PBL unit ends after only two weeks with a summative evaluation and/or a written report. Students want to know how they did on their last performance before being assessed again. This way, they may monitor their progress and improve their performances. This requirement places enormous pressure on tutors.

> When you're a student who isn't doing so well, you want to know about the mistakes you made in your report before submitting the next one. You want to know about the mistakes you made in the exam before the next one.

The group interviews showed that students demonstrate a good level of reflexive thinking in terms of their learning strategies, one of the predictors of students' engagement [42]. However, during the first years, being in a transient situation as they are, they sometimes act at the reflexive level while at other times, especially in a stressful situation, they don't. In these stressful periods, they expect receiving more key elements from tutors on a given PBL problem.

> At some point, we know all of our strengths and weaknesses. We know who [another student] to go see when we have such a problem because that person is better in that field and vice versa. A student is easier to reach than a professor. It's also less embarrassing.

> We spend much more time resolving problems than studying for the exam. I don't know why we keep on doing that, but we shouldn't. If you look at grading points, sometimes your exam is worth twice as more than your PBL report.

The students interviewed clearly emphasized the usefulness of internships and their practical aspect in connection with professional competency (most of them have had at least one work experience in the industry). This observation proves that the 'contextualization of knowledge' [53] predicts students' engagement and persistence in a curriculum that introduces it as one of its main characteristics, as it was also shown from the results of the questionnaire.

> I really made the connection between the PBL tutorials and my way of doing things in the workplace. It's when I wrote my internship report that I saw the way it worked for the project we had to carry out [during the internship]. To resolve problems, I operated the same way I did here in the tutorials.

Results from the questionnaire and the groups interviews were coherent with one another. Indeed, evidence of the importance of the predictors of students' engagement and persistence have been found in students' comments. Supports and stressors were clearly outlined from their answers and allowed us to better understand what specific factors in the environment played a critical role in explaining their engagement and persistence in the Electrical Engineering and Computer Engineering Curricula. Taking these converging results into perspectives, it is possible to make some suggestions to improve engineering education.

8. CONCLUSIONS

Some applications for engineering education may be considered in light of the results presented in this article, especially those related to perceived stress in the learning environment.

Generally speaking, the implementation of an innovative curriculum involves a certain number of unknowns and risks, as far as how students will react to it. Taking into consideration the results from both the questionnaire and the interviews, it is appears important to attempt to limit those risks by putting in place measures that will reduce perceived stressors and augment perceived supports. The 10 statements that are associated with the category 'Supports' and the 10 statements related to 'Stressors' (Table 4) give way to some interesting actions that can be taken in a PBL curriculum. As these results suggest when considering factors that may inhibit students' perceived stress, it is important to take into specifically into consideration first-year students' experience. Indeed, results show that students' transition to their 'new means of learning' and 'new ways of being supported by tutors' created some adjustment to. It is therefore critical to propose 'welcoming and introductory measures' in order to lower their perception of factors contributing to stress and to facilitate the emergence of those inhibiting stress.

Among the measures that may be implemented, it is important to mention making clear to students what are the objectives and expectations of the curriculum. Anxiety is less disruptive in situations where stimulus events are clear and unambiguous. When students know what to expect, they are more likely to invest productively in the curriculum. In such a predictive learning context, their environment is not perceived as increasing their initial stress. Indeed, as McKeachie and Svinicki [60] put it, it is important to give students 'a sense of where they are going and how they will get there' (p. 28).

One of the characteristics of an innovative curriculum is to be centred on the students (see Table 1). Among other things, this implies that tutors have at heart the well being of each student by showing him/her respect and consideration. A student should not be considered 'just a number'. In a supportive PBL curriculum, tutors should be able to notice and underline the quality of the work accomplished by students and, as was mentioned by students, in a timely manner. Tutors should remain available to follow up on students' inquiries, remarks, and questions. Because of that, students are much more appreciative of their tutors, they trust them more, and end up liking their program because it answers their needs well. As it is shown in the results, these elements have the potential to contribute significantly to perceived stressors that could be generated by the new curriculum.

Another element that is important to mention is the introduction of collaboration, rather than competition, amongst students in the innovative curricula. Competition gives rise to confrontation among students, as well as disagreement, everyone aiming at getting the best marks. On the contrary, students' collaboration should be encouraged, as well as peers' support.

As it was mentioned as one of the characteristics of an innovative curriculum, the evaluation process should be coherent with the spirit of the innovation. In a PBL learning environment, students should be allowed to demonstrate their competencies. It most curricula, the evaluation process is still based on individual performances and on the assessment of knowledge. Moreover, individual performances are often compared to an average score, therefore fostering competition among students. This is unfitted with the general spirit of PBL curricula. The use of criteria allows a teacher to distinguish individual performances for themselves, rather than compared to an average score. This, in return, as it was shown in the students' interviews, inhibits stress.

Finally, it should be noticed that the results shade light on the need to train professors who not only act as tutors in PBL, but are also expected to act as a 'mentor' vis-à-vis students' project. By being more readily apt to support students learning, at the cognitive and metacognitive levels, professors are better prepared to do along term follow-up on their performances.

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