



Published online: 8-22-2012

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IJPBL is Published in Open Access Format through the Generous Support of the [Teaching Academy at Purdue University](#), the [School of Education at Indiana University](#), and the [Jeannine Rainbolt College of Education at the University of Oklahoma](#).

Recommended Citation

Bédard, D., Lison, C., Dalle, D., Côté, D., & Boutin, N. (2012). Problem-based and Project-based Learning in Engineering and Medicine: Determinants of Students' Engagement and Persistence. *Interdisciplinary Journal of Problem-Based Learning*, 6(2). Available at: <https://doi.org/10.7771/1541-5015.1355>

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Problem-based and Project-based Learning in Engineering and Medicine: Determinants of Students' Engagement and Persistence

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and Noël Boutin*

Abstract

This paper presents results of a study conducted with undergraduate students involved in either problem- or project-based curricula (Medicine and Engineering, respectively) at the Université de Sherbrooke, Canada. The objective of the present research was to measure the impact of these innovative curricula on students' engagement and persistence in higher education. Our research question was: What determinants better predict students' engagement and persistence in innovative curricula such as PBL? Nine variables were examined as potential predictors of both factors (engagement and persistence). Results showed a variation in variables predicting engagement and persistence, with the most significant predictor being stress related.

Key words: problem-based learning, project-based learning, engineering education, medical education, engagement, persistence, stress

Introduction¹

Innovative curricula, such as problem-based learning or project-based learning, put students' engagement and persistence to the test. Indeed, they place a lot of weight on students' involvement during their university years. PBL and its derivatives usually require students to participate willingly in the meaningful learning activities proposed, mostly teamwork (Garcia & Roblin, 2008). The design of these innovative curricula often necessitates that students develop more autonomy and responsibility, as well as self-awareness about the value of these student-centered activities (Bédard & Béchard, 2009; Peterson, 2007). The pedagogical context created can be a source of concern for students (Carter, Fournier, Grover, Kiehl, & Sims, 2005) and affect their engagement and persistence in the curriculum. It is therefore important, if not critical, to investigate how these factors are influenced, especially at the curricular level.

Literature Review

Project-based learning and problem-based learning are sometimes confused with one another. Considering that they are both abbreviated "PBL," we suggest using different acronyms to avoid the confusion: PtBL for project-based learning and PmBL for problem-based learning. Moreover, both methods can assume a myriad of forms, depending on the discipline, curriculum or institution in which they are applied. It is therefore important to propose a clear statement about what each method is and the characteristics they share. In a recent article, Helle, Tynjälä and Olkinuora (2006) established that the "crucial aspects" of PtBL are that projects "involve the solution of a problem; often though not necessarily, set by the students himself" and "they commonly result in an end product (e.g. report, computer programme and model)," most often involving the construction of a concrete artifact. We will add a third and distinct characteristic reported in the article, "work often goes on for a considerable length of time" (p. 288). What about PmBL? Barrows (2002), one of the initial advocates of PmBL, reports that there are "four keys" to the method: Problems should be unresolved and ill-structured; learners should determine what it is they need to learn, illustrating that it is a student centred approach; teachers (tutors) should act as facilitators in the learning process; real world problems should be chosen, "making PBL an authentic learning process" (p. 119). Comparing both methods, with PtBL the learners control the learning process (teacher is an advisory at a distance) and with PmBL the learners orient the learning process (tutor is present throughout the learning process). Both methods function with small groups of students and start out with a problem (Walker & Leary, 2009). But, as it is stated by Helle et al. (2006), "in problem-based learning, students' activity is directed to 'studying', whereas in project-based learning, students' activity is directed to constructing the product" (p. 295).

Individual teachers can decide to use PmBL and PtBL in their classroom learning activities. But both methods can also be implemented at a curricular level. Such curricular, orchestrated changes can be called “innovative.” In innovative curricula, such as PmBL and PtBL, the pedagogical context students face is typically very different from what they have experienced before. Students do not always adapt easily to such changes. Their occasional lack of engagement and/or persistence in the program (Elder & Paul, 1998) may be due in part to the new pedagogical and organizational reality they are facing. Students’ engagement and persistence are critical elements for academic success, as many researchers have established (e.g. Eccles, Wigfield, & Schiefele, 1998; Pascarella & Terenzini, 1980; Pintrich & de Groot, 1990; Tinto, 1987, 2006; Wolters, 1998).

Legendre (2005) defined engagement as the time a student spends on a task. Pirot and De Ketele (2000) defined “academic engagement” as the capacity to mobilize affective, cognitive and metacognitive resources when undertaking a learning task, much like Hidi and Renninger (2006) describe the foundation of situation interest. Willis (1993) distinguished between “academic engagement,” which is linked to learning tasks, and “institutional engagement,” which refers to a more social perspective. Our view in this study is somewhere in between and could be described as “curricular engagement.” It could also be defined as one’s capacity to invest time and efforts, which last over time, when taking part in different curricular activities that make up the program. It has an affective component as well as a cognitive component.

Pintrich and Schunk (2002) defined persistence as a student’s conscious choice to pursue a learning activity—cognitively, metacognitively, and emotionally—despite the obstacle or difficulties encountered. Viau (1994) adds that students’ persistence is characterized by “tenacity.” When confronted with an obstacle or a difficulty, a persistent student will show tenacity and will continue to invest time and energy in realizing the learning task (Viau, Joly, & Bédard, 2004). As mentioned before, researchers have typically considered specific tasks or activities when trying to predict or explain students’ persistence, such as performing a task, passing an exam, or solving a problem. We are interested in students’ curricular engagement and persistence. Taking this perspective in mind we ask the question: How are students’ engagement and persistence affected by participation in innovative curricula? More precisely, what are the determinants of these two factors when taking into account the whole curricula, in this case, project- and problem-based curricula?

In order to address these questions, we completed a literature review to identify the variables most frequently taken into account when researchers and developers referred to the implementation of an innovative curriculum pertaining to students’ engagement and persistence. The nine variables found were grouped into four main dimensions (see Figure 1).

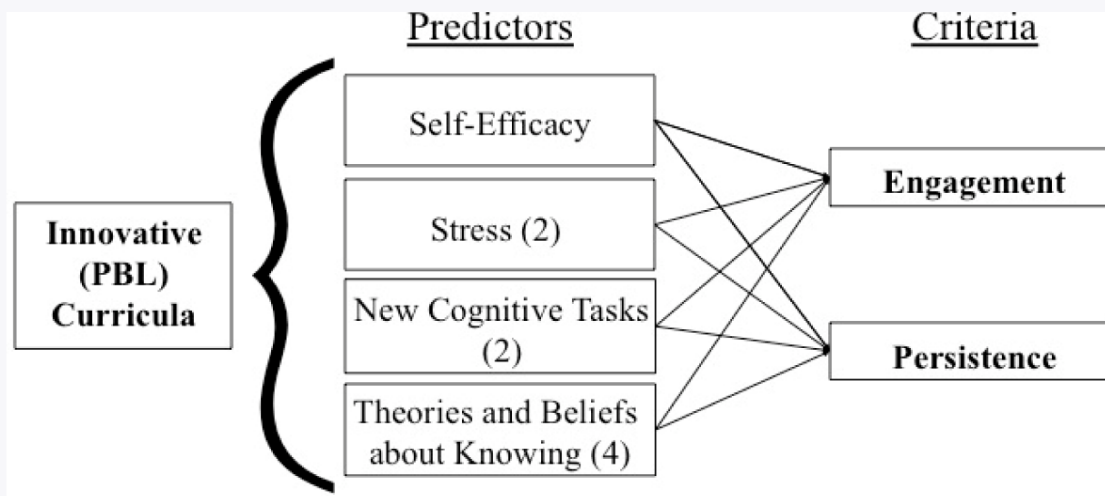


Figure 1. Determinants of students' engagement and persistence in innovative (PBL) curricula.

Self-Efficacy. Bandura's (1982) research on self-efficacy 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. According to Bandura (1997), self-efficacy can be defined as the judgment one makes on his/her capability to exhibit a series of specific behaviors for the purpose of reaching a certain level of achievement.

Stress. Admittedly, 'perceived stress' is more likely to reveal one's own level of stress (Cohen & Williamson, 1988; Cohen, Kamarck, & Mermelstein, 1983; Lazarus & Folkman, 1984). Indeed, the impact of a *stressful environment* on an individual is filtered by his/her perceptions of that environment. Mostly studied in relation to people's personal environment, stress has also been examined in the workplace (Vanier, 2002). Stress at work represents well what students experience when considering the many curricular activities they are faced with during their undergraduate studies. In the present paper, the variables contributing to stress will be called "*Stressors*," whereas the variables limiting or inhibiting stress will be called "*Supports*."

New Cognitive Tasks (NCT). Innovative student-centered curricula require students to rely on new cognitive tools. The literature points towards two of those cognitive tools: *Knowledge Articulation* (Collins, Brown, & Newman, 1989) and *Reflective Thinking* (Collins et al., 1989; McLellan, 1996). Knowledge Articulation refers mainly to students' capacity to distinguish knowledge and strategies applicable to a specific task (Järvelä, 1995). As for the ability to reflect on one's thinking process, Lajoie and Derry (1993) mentioned, "the specific importance of reflection is its role in consolidating the development of new strategies" (p. 322). Students' ability to rely on those two cognitive tools should allow predicting their engagement and persistence in the curriculum.

Theories and Beliefs about Knowing (TBK). Each individual has epistemological theories and beliefs about knowing. Perry (1970, 1981) has proposed a developmental scheme

to explain students' cognitive development throughout their undergraduate years. The different stages he proposed may be grouped in three categories: *dualism*, *subjectivism* and *relativism* (Finster, 1989, 1991). At the 'dualist stage,' students' perspective on knowledge is dualistic: right or wrong. At the 'subjectivist stage,' students add a perspective on knowledge that shifts to 'personal truths,' such as '*I think or believe that . . .*'. Finally, at the relativist stage, knowing is interpreted through 'contextual lenses;' truth becomes context-dependent. Perry's work appears very useful to predict students' engagement and persistence in innovative curricula that ask them to develop a relativistic epistemological posture. This last observation leads us to consider students' perceptions of knowledge, which pertains to the context in which it is presented or processed in project- or problem-based learning. Bédard, Frenay, Turgeon, and Paquay (2000) 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, and which should help predict students' engagement and persistence in a curriculum that introduces it as one of its main characteristics.

Research Question

Taking into account the determinants aforementioned, our research question became: What determinants better predict students' engagement and persistence in innovative curricula such as PmBL and PtBL?

Methods

Context and Curricular Characteristics

Medicine. In 1987, the Faculty of Medicine (as it was called at that time) at the Université de Sherbrooke introduced the problem-based learning method to its first-year students (Des Marchais, Bureau, Dumais, & Pigeon, 1992). The model adopted was the one developed and implemented at McMaster University earlier (Barrows, 1985). The Faculty of Medicine of the Université de Sherbrooke was the second one in Canada to adopt PmBL at the curricular level for all its pre-med students. From an external perspective, this change was partly brought about by mixed reviews from the Medical Association of Canada on the quality of training in universities and partly linked to new findings in the field of educational psychology, especially as it dealt with knowledge processing and learning. From an internal perspective, a survey revealed that professors found issues with the ways their "traditional curriculum" trained students and the ways they were asked to get involved in that process. Since then, many more medical programs have adopted PmBL, in full or in part, both in Canada and abroad (Norman, 2008).

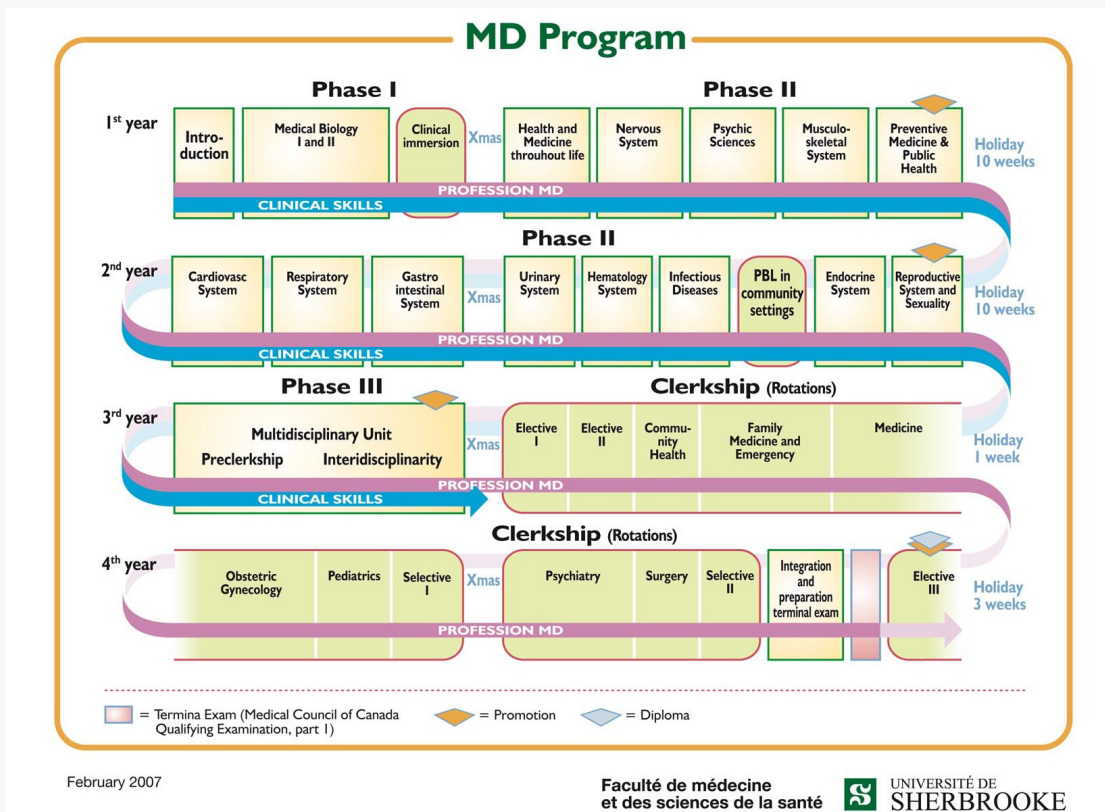


Figure 2. MD program at the Université de Sherbrooke.

The undergraduate medical curriculum for the MD degree requires students to complete a four-year program divided into distinct phases (see Figure 2). Phase I is composed of three modules aimed at reviewing students' biomedical knowledge. A "Clinical Immersion Practicum" follows it. Phase II of the curriculum, which lasts a year and a half, follows this first semester. Over that period, students have to complete 13 modules that cover essential medical topics or systems, each lasting between 3 to 4 weeks. Phase III requires students to engage in a four-month multidisciplinary module, which aims at approaching more complex medical problems. During those three phases, content is mostly presented in a PBL format. Clinical skills are taught throughout. For the remaining year and a half, students complete clerkship rotations in affiliated hospitals.

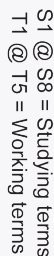
Engineering. In the 1970s and 1980s, engineering education programs in North America were essentially left unchanged, despite a growing trend towards competency-driven curricula in higher education. In the early 1990s, the profession stressed gaps between the readiness of young engineers to confront the challenges of the market and their background education (Todd, Sorensen, & Magleby, 1993; Tooker, 1992). Among the most common weaknesses noted was a lack of capacity to synthesize, to create, or to design, as well as poor communication skills. Moreover, Bordogna, Fromm, and Ernst (1993)

noted the fragmentation of scientific and technological knowledge, and suggested that undergraduate engineering education should be designed towards the integration of both.

Taking into account these critics, some of the staff at the Faculty of Engineering of the Université de Sherbrooke decided to review their undergraduate curricula and worked toward making them broader, less specialized, and more integrated, with an increased emphasis on design and social context. In 1996, the Faculty of Engineering opened its doors to major changes to the way undergraduate programs were delivered. First, the Mechanical Engineering Undergraduate Program adopted a project-based approach throughout its four-year program. Then, in 2001, after two years of planning, the Electrical Engineering (EE) and Computer Engineering (CE) departments presented two revised undergraduate programs, both structured around problem-based and project-based learning (PPBL²), and both oriented towards two broad pedagogical principles: learning by doing and student-centered teaching (Barr & Tagg, 1998). The EE and the CE programs share many common grounds in training their students. This is especially true in the first two years of the four-year curricula. These two curricula completely revised the way teaching and learning take place in class, that is, lectures are no longer given since the content is acquired through PmBL.

In both curricula, each semester is structured around a theme that helps situate learning (see Figure 3). These themes are linked to “Design Projects” that must be completed each term. Over the four-year curriculum, there are therefore eight projects to complete. The two main goals of the Design Projects are (1) to integrate the knowledge that has been acquired and (2) to draw upon that knowledge to conceive and complete an engineering project. The content is presented through six or seven PmBL units each semester (see Figure 3). During a PmBL unit, groups of ten to twelve students gather to think critically, to analyze, and to solve complex, real-world engineering problems. While doing so, they will be asked to find, evaluate, and use appropriate learning resources (Duch, Groh, & Allen, 2001). These resources will be required and reinvested in the realization of different projects.

Over the four-year curricula, there are eight terms spent at the university and four paid, compulsory co-op work terms. They are in fact training courses paid in companies. The “co-op program,” as it is often called, was introduced in 1966 and offers students the possibility of having work/study experiences. During the course of the curriculum, students alternate between studying at the University and working in the industry. This is not considered to be PtBL, for it is taking place “outside the curriculum” and representatives from the University do not supervise it.



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PBL format

Medicine. PmBL focuses on students' prior knowledge and beliefs, learning strategies, and the integration of knowledge from more than one subject-area (Evensen & Hmelo, 2000; Duch et al., 2001). PmBL in the MD program requires students to meet twice within a one-week period. During the first meeting, a team of students (7-8 people) is presented with a new problem. Students begin discussing among themselves with little intervention on behalf of the tutor. The discussion is catered around the formulation of hypotheses aimed at explaining the causes of the problem. These hypotheses are generated by questions students ask about the problem in order to better understand its content. Following the first meeting, students are provided with learning objectives and references. The latter are used to attempt to validate the hypotheses, answer unresolved questions, and attain the objectives. Two or three days later, the same group meets to cover the content of the literature received (e.g., research articles, book chapters) and exchange views on the value of the hypotheses and their possible answers to the questions. For the most part, the tutors only assist students' work. Their facilitating role implies that they "give them the space and freedom to do things their own way" (Savin-Baden & Major, 2004, p. 96). The tutor's role "is that of creating conditions in which students can exercise self-determination in their learning" (Savin-Baden & Major, 2004, p. 96).

Engineering. In order to better cater to the field of engineering, some adaptations were made to the original PmBL method (Barrows, 1985, 1996) in both the EC and EE curricula. One of the most fundamental changes relates to the tutor's role. As previously mentioned, the role of the tutor should be that of a facilitator, responsible for guiding students to identify the key issues in each problem and to find ways to learn about those areas in appropriate breadth and depth, as it is done in the MD program. Although this is not necessarily contradictory with the way tutors are asked to act in EE and CE curricula, both programs have decided that the tutor should keep his role of "content expert" who provides facts and answers as needed. Consequently, the tutor leads the exchanges and questions students on a regular basis to direct learning. Another important difference is that students have access to the problem, via a website, before the first PmBL meeting.

To complement PmBL, and to help the development of design skills in engineering, PtBL was used concurrently (Lachiver, Dalle, Boutin, Clavet, Michaud, & Dirand, 2002). Students are asked to conceive eight engineering projects throughout the four-year curriculum. These projects fall under the model called "project component" by Helle et al. (2006). In these types of projects, the aims are broad and the scope large. In addition, "the project is more interdisciplinary in nature and often related to 'real world' issues; the objectives include developing problem-solving abilities and a capacity for independent work" (p. 289). The PmBL sessions are held "parallel with the project." In addition, two other types of activities are embedded in the curricula, aimed at fostering students' acquisition

Characteristics			
#	Innovative Curricula	Electrical Engineering / Computer Engineering	Medicine
1.	Student-centered teaching and learning	<ul style="list-style-type: none"> • PPBL – no lectures • Laboratory and Procedural Workshops 	<ul style="list-style-type: none"> • PBL – few lectures • Program for academic support • Program aimed at teaching learning strategies • Program to promote clinical and professional integration — CPI (mentor with 6 students / 2Y)
2.	Contextualization of teaching and learning	<ul style="list-style-type: none"> • Engineering authentic problems in PBL Units • Design projects throughout the curriculum • Internship (working semesters) • Authentic problems PBL Unit 	<ul style="list-style-type: none"> • Paper medical problems • Clinical abilities taught throughout the curriculum • Clerkship rotations
3.	Reduction of “disciplinary compartmentalization”	<ul style="list-style-type: none"> • Multidisciplinary PBL units (e.g. Math, Physics, etc.) within a theme at each semester 	<ul style="list-style-type: none"> • Tutors linked to PBL units that are not their speciality
4.	Evaluation coherent with the spirit of innovation	<ul style="list-style-type: none"> • Evaluation reports • Problem-solving assessment • Peer-assessed performance for project-based learning 	<ul style="list-style-type: none"> • Objective Structured Clinical Examinations • Portfolio (CPI)
5.	Curricular emphasis on the transfer of learning	<ul style="list-style-type: none"> • Knowledge is presented as a spiral which builds from semester to semester and requires transfer of learning from students 	<ul style="list-style-type: none"> • Knowledge is to be transferred from a disciplinary paper-context to a multidisciplinary paper-context to a multidisciplinary real-context
6.	Collegiality among professors	<ul style="list-style-type: none"> • Problems are created by teams of professors • Weekly meetings of professors teaching at each semester 	<ul style="list-style-type: none"> • Multidisciplinary approach, which requires that professors to work together, share information and common terminology

Table 1. Characteristics of the three curricula: electrical engineering, computer engineering and medicine.

of procedural skills: “Procedural Practice Training” and “Laboratory Practice Training.” The combination of these four components makes up the distinctiveness of both the electrical engineering and computer engineering curricula.

To help distinguish the three curricula (EE, CE and Medicine) from an innovative, pedagogical and theoretical perspective, we used the six characteristics presented by Bédard, Viau, Louis, Tardif, and St-Pierre (2005). Table 1 presents the results of that comparative analysis. The Electrical and Computer Engineering curricula are presented together because, from a pedagogical point of view, they share the same characteristics.

Subjects

We met in person 480 undergraduate students from the aforementioned three programs. Table 2 and 3 presents the distribution of students according to their programs of study, as well as year and gender. 90% of the subjects were Caucasian and 73% had completed an internship in their fields prior to completing the questionnaire.

Survey

In order to investigate the four dimensions (predictors) and two factors (criteria), we developed a 95-item survey using a three-step validation process: content analysis (five experts), construct analysis (10 students), and item analysis (102 students). The latter analysis allowed us to calculate the internal consistency for each statement (item) using Cronbach’s alpha statistics. Items scored above 0.70 were kept. Normality assumption was verified. The distribution of items per variable is presented in Table 4.

The items in the survey were listed at random so as to avoid stereotyping. Each answer is rated using a five-point Likert-type scale (5 = totally agree; 4 = agree; 3 = more or less agree; 2 = disagree; 1 = totally disagree). Table 5 presents a sample of items for each dimension in the survey:

Data collection and analysis

We met with the subjects from all three programs during the winter term of the 2006-2007 academic year. Data were therefore collected for all students during the same year. Students were given the survey immediately after a scheduled PBL activity. Participation was voluntary. The average completion time was between 15 to 20 minutes.

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

Programs Genders	First Year	Second Year	Third Year	Total	%
Women	90	82	11	183	63.54 %
Men	42	51	12	105	36.46 %
Total	132	133	23	N = 288	100 %
%	45.83 %	46.18 %	7.99 %	100 %	

Table 2. Sample distribution according to the year and gender for medicine.

Programs Genders	First Year	Second Year	Third Year	Fourth Year	Total	%
Women	4	5	5	5	19	9.9 %
Men	30	55	56	32	173	90.1 %
Total	34	60	61	37	N = 192	100 %
%	17.71 %	31.25 %	31.77 %	19.27 %	100 %	

Table 3. Sample distribution according to the year and gender for electrical and computer engineering.

Dimensions	Number of items
Self-Efficacy	11
Stress - Supports	10
Stress - Stressors	10
NCT ³ – Knowledge Articulation	7
NCT – Reflexive Thinking	9
TBK ² – Contextualization	5
TBK – Dualism	5
TBK – Subjectivism	5
TBK – Relativism	5
Engagement	15
Persistence	13

Table 4. Distribution of items per variable in the survey.

Dimensions	Sample item
Self-efficacy	"I believe I have control over the competencies necessary to succeed in this program."
Stress—Supports	"The curriculum offers me opportunities of personal growth."
Stress—Stressors	"In general, I am faced with vague and imprecise expectations from teachers."
NCT—Knowledge Articulation	"In a learning situation, I am able to use my knowledge autonomously."
NCT—Reflexive Thinking	"In a learning situation, I regularly ask myself what I could do to reach the objectives."
TBK—Contextualization	"Knowledge to learn always appears more pertinent when it is presented through a concrete problem statement."
TBK—Dualism	"I believe that for each problem there is a one- and- only solution."
TBK—Subjectivism	"In all learning situations, it is important that I state my opinion."
TBK—Relativism	"I believe that solutions to a problem may vary according to the context."
Engagement	"I am encouraged to get involved because of the way the curriculum is designed."
Persistence	"Even when I don't understand something in the curriculum, I persist."

Table 5. Distribution of items per variable in the survey.

Results

We will first present results pertaining to students' engagement and then to students' persistence.

Students' engagement

Medical Curriculum. The analysis produced a significant model⁴ with six predictors (see Table 6). These six predictors account for 66% of the variance of students' engagement ($R^2 = .661$, $F = 91.201$, $p < .000$). The predictor, Supports, accounts for the largest proportion of variance, i.e. 59% for students in medicine.

Predictors	R square	Criterion
1. Supports (Stress)	0.59	Engagement
2. Contextualization (Theories and Beliefs about Knowing)	0.62	
3. Reflexive Thinking (New Cognitive Tools)	0.63	
4. Stressors (Stress)	0.65	
5. Subjectivism (Theories and Beliefs about Knowing)	0.66	
6. Self-Efficacy	0.66	

Table 6. Best predictors of students' engagement in medicine.

Electrical Engineering Curriculum. The analysis produced a significant model with four predictors (see Table 7). These four predictors account for 57% of the variance of students' engagement ($R^2 = .568$, $F = 33.854$, $p < .000$). The predictor, Supports, accounts for 48% of the variance in students' engagement in electrical engineering.

Predictors	R square	Criterion
1. Supports (Stress)	0.48	Engagement
2. Contextualization (Theories and Beliefs about Knowing)	0.52	
3. Stressors in the Curricula (Stress)	0.54	
4. Reflexive Thinking (New Cognitive Tools)	0.57	

Table 7. Best predictors of students' engagement in electrical engineering.

Computer Engineering Curriculum. The analysis produced a significant model with three predictors (see Table 8). This model accounts for 69% of the variance of students' engagement ($R^2 = .693$, $F = 60.268$, $p < .000$). Once more, the predictor, Supports, accounts for 60% of the variance of students in computer engineering.

Predictors	R square	Criterion
1. Supports (Stress)	0.6	Engagement
2. Reflexive Thinking (New Cognitive Tools)	0.67	
3. Contextualization (Theories and Beliefs about Knowing)	0.69	

Table 8. Best predictors of students' engagement in computer engineering.

Students' persistence

Medical Curriculum. The analysis produced a significant model with four predictors (see Table 9). These four predictors account for 34% of the variance of students' persistence ($R^2 = .336$, $F = 35.785$, $p < .000$). The predictor, Supports, accounts for the largest proportion of variance, i.e. 27% for students in medicine.

Predictors	R square	Criterion
1. Supports (Stress)	0.27	Persistence
2. Knowledge Articulation (New Cognitive Tools)	0.31	
3. Relativism (Theories and Beliefs about Knowing)	0.33	
4. Reflexive Thinking (New Cognitive Tools)	0.34	

Table 9. Best predictors of students' persistence in medicine.

Electrical Engineering Curriculum. The analysis produced a significant model with three predictors (see Table 10). This model accounts for 35% of the variance of students' persistence ($R^2 = .354$, $F = 19.028$, $p < .000$). Once more, the predictor, Supports, accounts for 27% of the variance of students in electrical engineering.

Predictors	R square	Criterion
1. Supports (Stress)	0.27	Persistence
2. Stressors (Stress)	0.32	
3. Subjectivism (Theories and Beliefs about Knowing)	0.35	

Table 10. Best predictors of students' persistence in electrical engineering.

Computer Engineering Curriculum. The analysis produced a significant model with five predictors (see Table 11). These five predictors account for 51% of the variance of students' persistence ($R^2 = .514$, $F = 16.481$, $p < .000$). The predictor, Knowledge Articulation (NCT), accounts for 32% of the variance of students in Computer Engineering.

Predictors	R square	Criterion
1. Knowledge Articulation (New Cognitive Tools)	0.32	Persistence
2. Stressors (Stress)	0.41	
3. Relativism (Theories and Beliefs about Knowing)	0.45	
4. Contextualization (Theories and Beliefs about Knowing)	0.49	
5. Supports (Stress)	0.51	

Table 11. Best predictors of students' persistence in computer engineering.

Discussion

Students' engagement

First, the number of variables in the model that best predicts students' engagement varies from one curriculum to another: 4 in EE, 3 in CE, and 6 in MD. The two engineering curricula show results that are close. The undergraduate medical curriculum however is

more distinct, which is not necessarily surprising considering that there are variations in the ways engineering and medical curricula have implemented PBL. Second, all three models account for a large percentage of variance regarding students' engagement, which on average, is 64%. This indicates that some variables of the initial theoretical model that was proposed, predict students' engagement well, foremost the variable "Supports."

Third, even more striking is the fact that, apart from the curriculum, the same variable (Supports—*Stress*) accounts for the largest proportion of the explained variance, on average 87%. We did not expect there would be such a high correlation between engagement and stress. Indeed, "perceived stress" in a given environment, allows for a better appreciation of that reality (Cohen et al., 1983). People actively interact with their environment. When doing so, they assess specific events as being stressful, or not, in light of available resources, within the environment and within themselves (Cohen & Williamson, 1988). More specifically, we looked at how stress was defined as it relates to work environment. Vanier (2002) defined stress at work as "a temporary adaptive process to stressful situations, which sometimes comes with physical and psychological consequences" (p. 3). There are therefore stressful situations within the work environment, which can be counterbalanced by Supports (e.g. being very appreciated by others) or confounded by Stressors (e.g. not receiving any support from others). The data suggest that, in all three curricula, when students perceive the curriculum (their learning environment) as a contributing element that diminishes their stress, they are much more likely to engage in the learning activities fully.

Furthermore, in both the EEC and the medical curricula, the predictive model also puts forth the variable Stressors. One could wonder how both variables appear in the same predictive model. It is important to realize that stress is not negative per se. It is the manner in which one deals with it which may be the problematic (Cohen & Williamson, 1988; Lazarus & Folkman, 1984). To learn, to be engaged, students need to be challenged to a certain extent. The right equilibrium between stress and available resources will generate productive energy thus, stimulating students. It is therefore not surprising that both Stressors and Supports appear in the same model and that both predict engagement, though more so for Supports.

Finally, there are two other predictors in all three models: Contextualization (*TBK*⁵) and Reflexive Thinking (*NCT*⁶). Results here are coherent with problem-based and project-based learning environments. Indeed, both problems and projects attempt to present a more explicit view of professional reality (Barrows, 1996; Lachiver et al., 2002). Students aim at finding such professional windows during their enrollment in higher education (Viau et al., 2004). It is therefore to be expected that they engage themselves more in a curriculum that situates knowledge and the suggested learning experiences using real-context problems.

Reflexive thinking is also a prevalent component of the tutoring process during

PmBL sessions (Barrows, 1996). Students' reflection allows them to become more effective learners and problem solvers, while gradually developing "an internal cognitive model of expertise" (Collins et al., 1989, p. 482). The data suggest that students' self-awareness of such abilities and their outputs should correlate with their engagement in a problem-based and project-based curriculum.

Students' persistence

First, contrary to the results obtained with the engagement variable, the three models of persistence account for a lesser percentage of the variance of students' persistence, which on average is 40%. There are therefore other predictors that should have been taken into consideration in order to better predict persistence (Pintrich & Schunk, 2002).

Second, as was the case with the variables best predicting engagement, the Supports (*Stress*) variable accounts for the largest proportion of the explained variance (on average 78%), but only for two of the three curricula: EE and Medicine. When considering students' persistence, such a result can be interpreted in light of what is known about the notion of "resilience," a concept that is near to this factor. In psychology, resilience has been defined as the adaptation to significant adversity or trauma (Luthar, Cicchetti, & Becker, 2000). While personal attributes (e.g. being outgoing, bright, and having positive self-concepts) related to resilience are often discussed, other attributes associated with the environment are also mentioned. These include both family-related variables (e.g. having close bonds with at least one family member) and community-related variables (e.g. receiving support or counsel from peers) (Werner, 1995). As demonstrated in our study, support from peers is particularly effective in the PBL curricula studied. It can therefore be said that when a curriculum offers its students "learning supports," be they related to professors, specialized personnel (e.g. psychologists), or built-in measures (time to complete the expected group work), students tend to show more persistence.

Contrary to previous results, the variable that appears first in the CE curriculum and that accounts for the largest portion of the variance is Knowledge Articulation (*NCT*). The prevalence of this variable in the significant model predicting students' persistence in CE may be explained by considering two complementary views: (1) the nature of the knowledge to acquire and (2) the characteristics of the CE PPBL curriculum. The first explanation to consider is that students have developed particular learning strategies coherent with the nature of the knowledge to be acquired. Indeed, computer engineering is based primarily on mathematical knowledge. To assimilate such knowledge requires that students develop software design skills, as well as a capacity to find computer system solutions using real-world problems. If persistence is defined as the choice one makes to pursue an activity when faced with difficulties (Pintrich & Schunk, 2002), it is likely that when CE students can understand and articulate abstract (mathematical) knowledge, they are more

likely to persist in the curriculum. The second explanation focuses on the characteristics of the CE PPBL curriculum. Tutors in PmBL sessions place great emphasis on the need to articulate one's knowledge, as well as the reasoning process (Järvelä, 1995). For McLellan (1996), "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). The data suggest that students in computer engineering (CE) are more likely to persist in the curriculum when they "articulate their knowledge, reasoning, or problem-solving processes in a domain" (Collins, Brown, & Newman, 1989, p. 482). Other studies also report distinctions between CE students and other engineering students. For example, in a study looking at the differences between computing and non-computing students, Bélanger, Lewis, Kasper, Smith, and Harrington (2007) identified emotional intelligence (EI) as a predictor of academic success and found a significant difference between computing and noncomputing students in regard to emotional intelligence and coping strategy of accommodation in a stressful situation.

Engagement and Persistence

The results related to both criteria downplay the role of the variable, "Self-Efficacy," in predicting both students' engagement and persistence. This was also an unexpected finding. Indeed, most explanatory models of students' motivation (e.g., Viau, 1994) and persistence (e.g., Bandura, 1997) present self-efficacy as being one of the most prominent variables. This "no-show" could be explained by the fact that we did not ask the students to consider a specific task (exam, homework, etc.) when completing the questionnaire. Statements were all directed toward their engagement and persistence in relation to the curriculum (e.g. *I am encouraged to get involved because of the way the curriculum is designed*). It is likely that different variables come into play when considering a four-year endeavour such as "successfully completing your program." Finally, we were not attempting to analyse an explanatory model, but a predictive model. This may explain in part the lesser importance of the Self-Efficacy variable in the different models presented.

Instructional Implications for PBL

Here are some instructional implications we would make for PBL curricula. These recommendations essentially relate to the result showing that the most significant predictors for students' engagement and persistence were stress related. Students indicated that one of the aspects that most reduced their stress was that they appreciated the autonomy they were given in the curriculum (Bédard, Lison, Dalle, & Boutin, 2010). Indeed, in both curricula, there are many hours built-in to the weekly schedule as "free slots" or "open time" for group meeting, study time and even extracurricular activities. This would be an important recommendation for anyone looking at implementing PBL in a curriculum, that

is, planning such “non-directed activities” and allowing students to take charge of what they will do with them and how.

Another aspect that was mentioned as contributing to stress reduction is peer support. The way this was fostered in the curricula was by sending out the message that collaboration was more valuable than competition (Bédard, Lison, & Côté, 2010). Moreover, the assessment of students’ learning is designed not to encourage such competition (Lachiver et al., 2002). Two recommendations would follow based on practice in each curricula. As much as possible, assessment should be “criteria-based,” not done on a comparative basis, which would undermine their willingness to collaborate.

In Engineering specifically, students very much appreciate that exams are preceded by “formative evaluations,” which allowed them to better situate what they learned “before it counts.” In medicine, students mentioned that not being able to review their individual exams contributed to their stress (Bédard, Lison, Dalle, & Boutin, 2010). **Though this measure** was adopted to prevent cheating, it appears not to be perceived favourably, especially in light of the way PBL proposes to discuss and acquire the learning material.

Another component that is an issue with students is the “rigidity of the PBL curriculum,” causing them stress. Indeed, all three curricula function on a “group basis.” It is very difficult for a student to take any kind of distance or not to follow the group “pace of learning.” Moreover, a failure at an exam causes serious problems regarding one’s capacity to keep up. PBL curricula will need to be more flexible. Built in measures that allow some students to take different paths than others, whether by choice or because of undesired circumstances, should be offered.

Conclusion

Despite the inherent differences as learning methods, PmBL curricula as well as PtBL curricula share many common characteristics. They are both considered as innovative, especially from a student’s perspective. Indeed, most high-school level students will not have previously experienced such a learning environment. One of the most striking characteristics of PPBL curricula is the importance allocated to group work. Whether it be during PmBL sessions or while working on engineering projects, students are now, more than ever, expected to collaborate and cooperate with their peers (Bédard & Béchar, 2009; Carter et al., 2005; Walker & Leary, 2009). This is also true for medicine students, but to a lesser extent. In EE and CE curricula, student performance is being assessed in light of their contribution to group work.

All three programs have designed and implemented well-crafted schedules, which offer students more supervision during their work and study. The process requires time, energy, planning, and autonomy. Data demonstrate that stress related variables have become a central element of students’ engagement and persistence when considering

such a program of learning tasks and activities. We, as educators or heads of program, should therefore take these results into consideration when planning to evaluate the impact stress can have on students.

Notes

1. This research was made possible by a grant from the Social Sciences and Humanities Research Council of Canada.
2. The acronym PPBL is proposed as a way to highlight the use of both problem-based learning and project-based learning in the same curriculum.
3. NCT: New Cognitive Tasks; TBK: Theories and Beliefs about Knowing.
4. A significant model illustrates the “best” regression equation or the equation that maximizes the R².
5. TBK: Theories and Beliefs about Knowing.
6. NCT: New Cognitive Tasks.

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