Impact of a networked computer-assisted project-based pedagogy on motivational beliefs and work involvement of secondary-level students

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TRANSLATION

Prepared for:
2002 Pan-Canadian Education Research Agenda Symposium
"Information Technology and Learning"
April 30 – May 2, 2002
Crowne Plaza Montreal Centre Hotel
Montreal, Quebec

ABSTRACT

The principal aim of this study was to examine the repercussions of introducing networked computer-assisted project teaching in secondary level classes (Protic project) on instructional organization of the classroom, the learning strategies students adopt, satisfaction of their learning needs, their choice of academic goals, their motivational beliefs and engagement. To carry out this study, 182 third-year secondary school students in six classes filled out questionnaires on the features of their classes, their motivational beliefs, and their learning processes in French and mathematics. The six classes represented three different contexts, i.e. two Protic classes, two enriched classes, and two regular classes.

First, we compared students' perceptions of Protic classes with those of enriched and regular classes in French and mathematics. The results suggest that the climate in Protic classes stood out from that in other classes in terms of cooperation and investigation, and to a lesser extent, innovation and individualization. Learning strategies differed mainly in terms of constructing knowledge, in-depth processing of content, and, in math classes, self-regulation. Also, in Protic classes, avoidance goals were less evident and mastery goals more evident in math classes. These students expressed more satisfaction with their needs in math classes, accorded higher value to French and math, and were more engaged in French classes.

With regard to relationships among variables, students' self-efficacy was related to satisfaction of their needs in terms of belonging, power, and adopting mastery goals. The value given to academic subjects was positively related to the instructional organization of the class and the adoption of mastery goals, and negatively to the adoption of avoidance goals. Engagement was significantly related to the strategies students adopted, including mainly self-regulation of learning.

The results overall suggest that relationships between the teaching process and the learning process are similar from one context to another, but that achievement levels are higher in classes using networked computer-assisted project teaching.

Success for all students without lowering requirements is an important objective for education officials in western countries. However, even though adolescent development may not always be as problematic as it is often perceived to be, many young people experience hardships during this period of their lives. In Quebec, the academic dropout rate, which was 10.4% among 17-year-olds in 1999, (MEQ, 2001), is still a matter of concern and hence represents a major academic problem. More generally speaking, most western countries are witnessing a decline in motivation among students when they reach high school (Carnegie Council on Adolescent Development, 1988; Conseil supérieur de l'éducation, 1995). Hence, soon after they enter high school, there is an observed deterioration in their interest in school and in intrinsic motivation (Ames, 1992), self-esteem (Harter, Whitesell and Kowalski, 1992), feelings of self-efficacy and motivational beliefs (Anderman, Maehr and Midgley, 1999), coupled with increased anxiety and learned helplessness (Eccles and Midgley, 1989). Some researchers (Eccles, Midgley, Wigfield, Buchanan, Reuman, Flanagan and MacIver, 1993) pose the hypothesis of a poor fit between adolescents' development needs and the learning environment offered by most secondary schools. According to Eccles *et al.* (1993), academic organization at secondary level may be characterized by six operating patterns that might be responsible for this state of affairs.

First, at middle school level [*premier cycle*], teachers exercise more control over their students and leave them few opportunities for making decisions about what they learn. To this is added the fact that relations between teachers and students are less personal and not as warm, and trust between them diminishes. In addition, the transition to secondary school is associated with an increase in more impersonal teaching approaches, such as large group lecture-style classes, a decrease in team work, and the almost complete disappearance of individualized approaches. Next, secondary level teachers are distinguishable from elementary teachers in that they are less concerned with students with learning difficulties and feel they are less competent to work with such students. Eccles *et al.* (1993) state as well that the academic tasks offered to students in the first year of secondary school seem to require a lower level of cognitive skills than at the end of elementary. This observation somewhat shakes up our conceptions about teaching, which is supposed to be efficiently organized by subject specialists, but observational studies shows only a very small proportion of academic activities sets students' creative or expressive skills in motion, and that note-taking is very widespread. Lastly, learning assessment is stricter at secondary level and raises more phenomena of social comparison, which leads to lower self-confidence among many students. To summarize, the theory proposed by Eccles *et al.* (1993) suggests that the difficulties experienced by secondary schools in meeting adolescents' needs for autonomy and control result in a decline in their intrinsic motivation and interest in school.

It is partly in response to these problems that many specialists favour instructional approaches that encourage greater participation by students. From these approaches have arisen strategies such as computer-assisted project teaching, regarded as a way to enable students to experience significant, complex learning situations (Lin and Hsieh, 2001). When the emphasis is placed on learning, teachers should gradually become aware of the necessity of altering the way they do things and their conceptions of how students learn. According to what emerged from the assessment of several instructional experiments using ITCs, new technologies offer undeniable opportunities for stimulating learning processes, anchoring them in a particularly broad and rich body of skills, and increasing the mastery of learning itself (Grégoire, Bracewell and Laferrière, 1996). Researchers on the Apple Classrooms of Tomorow project (Fisher, Dwyer and Yocam, 1996), which consisted of fully equipping selected classrooms across the United States, reported results in writing, mathematics, and problem-solving skills that proved to be higher in ACOT classes than in regular classes.

Other studies, however, suggest that access to computer equipment does not in itself guarantee that the equipment will be used regularly by teachers and students. Newhouse and Rennie (2001) report that even when many computers are placed at students' disposal, the impetus is not always such as to make frequent, effective use the rule. Cuban, Kirkpatrick and Peck (2001) offer two explanations for this. First, it must be realized that any technological revolution takes a certain amount of time before spreading to the general population. A second explanation relates to the context of high schools that do not do much to promote new practices.

This study is intended to verify whether the introduction of computer-assisted project teaching using portable computers in high school classrooms is really associated with an instructional organization that stands out from other classrooms and better meets student needs. The study also attempts to verify whether this new form of organization is likely to lead students to develop effective learning strategies, such as skills building and in-depth processing of concepts, and casting aside ineffective strategies such as task avoidance. Lastly, the study examines whether students in these classes will adopt mastery goals in greater numbers and be more engaged in their studies.

Project approach

Project teaching has a long history, but it was at the turn of the last century that experiments and theorizing began on the subject of project instruction. For Dewey, individuals learned more by doing than by listening. It was by constructing projects and doing experiments with partners that students learned. Many European and American educators, such as Freinet, Makarenko, Piaget, and then Brown, Pea and Barron, contributed variously to the research. Project instruction covers a multitude of practices, but to isolate the main characteristics of the approach, we may cite Huber (1999):

> Thus we will describe "project" as an action that materializes in the fabrication of a validating socializable product, and at the same time as it transforms the milieu, also transforms the identity of its authors by producing new skills through solving problems encountered. (p. 43). [*Translation*]

Project work normally involves three phases, i.e. preparation, execution and exploitation. Each of the phases includes two or three major activities (Grégoire and Laferrière, 2001). The preparation phase includes choosing a project, pinpointing the required resources, and organizing the work. This phase arouses curiosity, interest and questioning among students and promotes their progress in developing methodological and social skills. The second phase is characterized by the development of a project within teams and by coordination and synthesis of individual contributions. The use of new technologies permits access to up-to-date data on concrete problems. Skills in planning, conceptualization, analysis and synthesis are regularly called upon. To these are added skills relating to team organization of work and collaboration. Peer discussion may fulfill several functions in the knowledge-building process. According to Driver (1995), this creates a space in which ideas implicit at the outset become explicit, studied and made available to others for consideration. To do this, participants clarify their own conceptions so as to submit them and build their own schemes based on other people's ideas. Lastly, the instructional exploitation phase consists of going back over the whole project and following up. It is at this time that students incorporate different disciplines and come to recognize and name effective strategies.

Projects enable students to experience complex and significant situations, become aware of their work methods, and mobilize cognitive strategies enabling them to process problems in depth. To do this, the teacher must accept a role of becoming more an instructional mediator who accompanies and guides students throughout the project, creates a conducive climate, solicits their cooperation, and helps them process information and use information technologies (Arpin and Capra, 2001). As for students, if they invest in the project voluntarily, they participate actively in building their learning, and mobilize different cognitive and metacognitive strategies.

Instructional organization of the classroom and the learning climate

In an academic setting, it is shown that a set of contextual variables, ordinarily designated by the expression *learning climate* (Michaud, Comeau and Goupil, 1990), has repercussions for students' learning. According to Moos (cited by Fraser, 1986), the learning climate is made up of the following three major dimensions, i.e. interpersonal relations, personal development and system management. Research studies such as that by Walberg (1969) reveal that the climate in which learning takes place has an important effect on students' academic performance. According to Deci and Ryan (1987), when conditions are favourable and motivation intrinsic, they lead to better learning.

It appears that the learning climate may indeed influence students' motivation, based on three factors: organization governing relations among students, the teacher's teaching style, and the task at hand. With regard to the first factor, relations among students may be competitive, cooperative or individualistic in nature. A classroom structure that promotes self-determination enables students to feel they are more competent (Vallerand and Thill, 1993), and teachers who encourage autonomy in their students create feelings of competence and self-determination among them and maintain their intrinsic motivation. Also, the way teachers are perceived by their students influences their motivation. Teachers who have an opportunity to forge more personal relations with their students have more chance of arousing their interest and engagement. Lastly, students' perception of the utility of the activity also influences their academic motivation. Students who grasp the importance of the tasks to be accomplished and understand the reasons for doing them will have a taste for engaging themselves and persevering in academic tasks.

It is our belief that an instructional organization of contexts that promotes learning by networked computer assisted project should be characterized by innovation, collaboration, research, and individualization of instruction. These characteristics should contribute to the satisfaction of students' needs, and be linked to the adoption of high-level learning strategies and learning-centred academic goals.

Students' academic goals and learning strategies

Several research studies (Ames, 1992; Roeser, Arbreton and Anderman, 1993) show that the instructional practices teachers adopt are linked to different motivational directions and learning strategies among students. An observational study by Meece (1991) suggests that teachers whose students favoured mastery goals tended to promote significant learning, adapt teaching to their students' particular needs, and favour autonomy and collaboration.

Mastery goals are pursued by students wishing to accomplish an activity, a plan to appropriate knowledge for learning that occurs for its own sake (Dweck, 1986; Hidi and Harackiewicz, 2000). Associated with these goals are greater persistence in the face of difficulties or even failure, recognition of the importance of effort, and acceptance of certain risks. In fact, these students tend to consider failure as a normal stage in the learning process (Boileau, Bouffard and Vezeau, 2000). Pintrich and Schrauben (1992) examined the nature of learning goals among cohorts of high school and university students, and concluded that students who pursued mastery goals had a greater tendency to engage cognitively in learning self-regulation activities and to utilize cognitive and metacognitive strategies such as planning and assessment of their learning process.

Performance goals, on the other hand, are associated instead with the search for a positive assessment of skills, avoiding negative judgments, a desire to surpass others, and the importance given to skills at the expense of effort (Hidi and Harackiewicz, 2000). According to Pintrich (1989), students who pursue performance goals like to meet challenges, and prefer learning strategies that demand a minimum of effort. However, performance goals are not exclusively negative in character. Bouffard, Boivert, Vezeau and Larouche (1995), as well as Archer (1994), acknowledge the following strengths in students adopting them, provided that they already have a high level of perception of their own competence: cognitive engagement, use of adaptive learning strategies, and academic performance. On the other hand, errors and hardships experienced are perceived negatively because they are regarded as obvious indicators of a lack of competence (Boileau, Bouffard, Vezeau, 2000).

Avoidance goals are a less well documented type of goal in the theory of goals. This modality was added to the list to distinguish students who pursue performance goals from those who pursue goals in light of doing only a bare minimum to avoid failure (Bouffard *et al.*, 1999). Avoidance goals in the classroom translate into strategies that attempt to slow down group work and lower requirements. From this point of view, certain researchers have revised the original binary model of the goal theory (Dweck, 1986; Nicholls, 1984), adding this third category to it. As well, several factorial analyses validated the independence of the three types of constructs (Laguardia and Ryan, 2000).

Students' needs

Educators and researchers (Marks, 2000; Glasser, 1986) consider that many students are content to do mediocre work in school, and in many cases do no work at all. Glasser estimates at no more than half the number of secondary school students who are prepared to make an effort to learn, and states the situation shows the limitations of traditional academic structures. One proposed solution is to have teachers intervene more actively so as to fulfill their students' fundamental needs. These needs may be conceptualized as needs for survival, belonging, power, freedom and fun. This is the way that Charles (1996) presents Glasser's ideas about interventions required to meet students' needs.

> Students gain a feeling of belonging whent they are called upon to participate in classroom activities, get attention from their teachers, and have an opportunity to ask questions about the class. They feel empowered when their teachers ask them to decide together what subjects will be studied in class and what working method is to be used. Students have fun when they are allowed to work together, discuss, participate in interesting activities, and share their accomplishments with their classmates. They have a feeling of freedom when they are allowed to make responsible choices (p. 183). [*"Back-translation" to English: Translator's note - The original version of this work was catalogued but not available for reference at the time of writing this translation.*]

For Glasser (1986), academic activities should contribute to the satisfaction of students' basic needs. He proposes that teachers set aside traditional teaching practices and demand high quality work from their students. Leaving students more leeway in choosing their subjects, favouring reviews of work learned, creating a warm climate in the classroom, and asking students to do more than just useful work, are among the suggestions Glasser makes that could very well apply to what is recommended in the Protic classroom.

The Protic classroom

The Protic program is an initiative of the Les Compagnons-de-Cartier school and the Découvreurs school board (Commission scolaire des Découvreurs, 1997). The report on the first phase of the project (Laferrière *et al.*, 2000) states that the Protic program's designers were driven by the conviction that a break had to be made with traditional instruction, and

> (…) direct their thought to two main parameters: first, ITCs should be fully integrated into the instructional plan if we wish to make it a working tool on the same basis as a book or a grammar; second, to achieve such a full integration, we must develop an approach that makes use of the new instructional trends, i.e. project learning, cooperation among students, and development of cross-skills. (p. 10). [*Translation*]

The Protic project (Giguère, Grégoire and Bergeron, 1997) recruited 64 students entering their first year of high school (two class groups) and who wished to begin an active learning process extending throughout their high school years. Every year, a new cohort was added, raising the number of students to 192 during the 1999-2000 academic year. Teachers were recruited on the strength of the interest in working by project and their wish to integrate ITCs into their teaching. Their instructional models had in common developing their students' autonomy, feelings of responsibility, and cooperation. Each teacher was responsible for a given core subject matched with a secondary level subject, and acted as home teacher for a class, while intervening regularly in the second class at the same level. This distribution of duties enabled opportunities for teacher-student exchanges to be doubled. Human and material organization was thereby placed at the service of the project (Grégoire, 1997), and staff of the school board's educational services followed the teachers' approach very actively. Teachers in readiness training made their own contribution during practice teaching assignments. In the Protic classroom, every member of the community had a portable computer connected to the network, both in the school and at home (Laferrière *et al.*, 2000), but the computer and what accompanied it were not the principal object of the studies.

> Integration of computers into the classroom is meaningful only in the context of active learning. Indeed, it is not through person/machine interaction that the Protic program sets itself apart, but rather through the interaction among individuals who have networked computers to learn program content (or have it learned). (p. 17). [*Translation*]

The use of computers thus serves the achievement of learning projects that may include more than one subject. Project instruction in fact creates a favourable context for integration of the computer when it is used as a tool to multiply opportunities for information exchanges and processing. The teacher's role in Protic classes thus necessitates the creation of conditions conducive to creating a true learning community that makes possible progressive development of intellectual autonomy among its members. Students, for their part, participate in choosing, designing, and carrying out learning activities. They have their say in the division of labour, and are responsible for the portion of the work assigned to them (Laferrière *et al.*, 2000). Every year, a new team of teachers involved in developing this approach leads the student community. The student group that is the subject of our study is in its third year of operation in this framework.

Research objectives

1- To examine the features that distinguish Protic classes from others in the areas of: instructional organization of the classroom, learning strategies students adopt, level of satisfaction of students' needs, academic goals and motivational goals and engagement.
2- To examine the relationships between classroom organization and variables linked to the teaching-learning process, such as learning strategies, satisfaction of needs, and students' academic goals.
3- To examine the extent to which variables linked to classroom organization, learning strategies, satisfaction of needs, and students' academic goals can predict motivational beliefs and engagement.

Method

1. Participants

Six third-year secondary level classes, made up of 182 students. Of this number, 53 were enrolled in two Protic classes, 50 in two enrichment classes (international education program) and 79 in four regular classes (two French and two math). As the students in regular classes were not the same in French as in math classes, the sample included 143 students in French and 142 in math. Average age of the students was 15.1 at the time the data were collected. Students in the two regular classes were slightly older than those in the Protic classes and enriched classes (15.4 for the former and 15.0 for the latter).

2. Measurements

The following scales describe the instructional organization of the classroom, learning strategies, and students' motivational beliefs and engagement. They were submitted to the students twice, the first time for the French class and a second time for the math class.

2.1 Instructional organization of the classroom

Four scales were used:

- *Collaborative learning* (5 items, alpha=0.80). This scale permits an estimate of the extent to which classroom activities encourage exchanges among students and promote collaborative learning.
- *Investigation* (4 items, alpha=0.78). Inspired by the Fraser scale (1990), this scale measure the extent to which students do research to check their ideas and find answers to their questions.
- *Innovation* (4 items, alpha=0.60). A translation of the scale developed by Moos and Trickett (1974), this scale measures students' perceptions with regard to instructional innovation, and particularly the active role that has been passed down to students.
- *Individualization* (5 items, alpha=0.77). Translated and adapted from Fraser's scale (1990), this scale indicates the extent to which students have an opportunity to talk to their teachers, as well as the degree to which the latter are concerned with their students' well-being and social development.

2.2 Students' learning strategies

Three scales:

- *In-depth processing* (9 items, alpha=0.78). This scale, a translation of one developed by Roeser, Arbreton and Anderman (1993), indicates the extent to which students adopt effective cognitive strategies such as planning, systematic study, and searching for significant links.
- *Knowledge construction* (5 items, alpha=0.83). Drawn from the SPOCK scale developed by Shell *et al.* (1995), this scale measures strategies such as the establishment of links among ideas, facts and disciplines.
- *Self-regulation of learning* (5 items, alpha=0.72). This scale also comes from the instrument developed by Shell *et al.*; it measures the point to which students organize their learning and activate cognitive and metacognitive processes in their approach.

2.3 Academic goals

The following three scales are inspired by Roeser, Arbreton and Anderman (1993).

- *Mastery goals* (6 items; alpha=0.84). These are goals centred on learning and mastery of content being studied.
- *Performance goals* (4 items; alpha=0.64). These are goals motivated by the desire to surpass others.
- *Avoidance goals* (3 items, alpha=0.60). This scale assesses the recourse to avoidance strategies when students are faced with difficulties.

2.4 Personal needs

Four scales were constructed based on descriptions provided by Glasser (1986).

- *Belonging* (2 items; alpha=0.50)
- *Freedom* (3 items; alpha=0.45)
- *Power* (2 items; alpha=0.72)
- *Fun* (3 items; alpha=0.75)

2.5 Motivational beliefs

Two scales:

- *Self-efficacy* (6 items, alpha=0.78). This scale is drawn from a questionnaire developed by Midgley and Maehr (1990) and assesses the student's feelings of competence.
- *Intrinsic value* (9 items, alpha=0.86). This scale is a translation of a scale developed by Pintrich and De Groot (1990) and measures the student's interest in the academic subject.

2.6 Engagement

- The *engagement* scale (4 items, alpha=0.77), adapted from Moos and Trickett (1974), describes the amount of attention and energy students put into their assignments.

Results

Analyses are structured in terms of the study's three objectives:

1. Differences between Protic classes and other classes

Analysis bears on what distinguishes Protic classes from other classes, regular and enriched. We assume that the former, in addition to making intensive use of ITCs, are favoured with project instruction, as well as collaborative learning. It was not possible to resort to variance analysis with repeated measurements, given that the control groups in French and math were not the same. For this reason, tests were conducted separately for each subject.

With respect to instructional organization of the classroom, six of the eight variance analyses yielded significant results. First, in French, the contexts were distinguished according to level of research ($F_{2,140} = 15.46$, $p<.001$) and the level of collaboration among students ($F_{2,140} = 9.27$, $p<.001$). Additional analyses (Tukey tests), showed that students do more research in Protic classes than in the other two contexts, and collaborate more than in regular classes. With mathematics, the contexts are distinguished in terms of investigation ($F_{2,139} = 41.63$, $p<.001$), innovation ($F_{2,139} = 22.30$, $p<.001$), individualization ($F_{2,139} = 36.98$, $p<.001$) and perceived collaboration ($F_{2,139} = 36.94$, $p<.001$). In all four cases, Tukey tests showed that averages were higher in Protic classes than in the other two contexts.

The following analyses show that learning strategies adopted by students the three contexts differ significantly for the majority of indicators. For French classes, the major differences involved knowledge construction ($F_{2,140} = 4.53$, $p<.05$) and, even more marginally, in-depth processing ($F_{2,140} = 2.90$, $p<.06$). In math classes, differences affected knowledge construction ($F_{2,139} = 16.70$, $p<.001$), in-depth processing ($F_{2,139} = 11.46$, $p<.001$) and self-regulation ($F_{2,139} = 3{,}87$, $p<.05$). Subsequent analysis (Tukey tests) showed that students in Protic classes had higher averages for knowledge construction and in-depth processing. Protic classes surpassed regular classes in self-regulation of learning.

Analyses of academic goals are fairly conclusive as well. In French classes, it was avoidance goals ($F_{2,140} = 7.64$, $p<.001$) and performance goals ($F_{2,140} = 3.29$, $p<.05$) that set the contexts apart. In the case of the former, Tukey tests revealed differences between Protic classes and the other two contexts. In the latter, significant differences emerged between the Protic classes and regular classes. In math classes, the same was true for mastery goals ($F_{2,138} = 13.02$, $p<.001$) and avoidance goals ($F_{2,139} = 12.01$, $p<.001$). In both cases, Protic classes stood out from the other two.

With respect to satisfaction of students' needs, the results of analyses make it possible to draw different portraits according to the subjects that were given instructional intervention. In French, students in Protic, enriched and regular classes did not express significantly different satisfaction levels. In math classes, Protic students expressed higher satisfaction levels than those in the other two contexts with respect to belonging ($F_{2,139} = 14.97$, $p<.0001$), freedom ($F_{2,139} = 16.12$, $p<.0001$), power ($F_{2,138} = 14.32$, $p<.0001$) and fun ($F_{2,139} = 38.29$, $p<.0001$). Tukey tests also revealed that satisfaction levels are not significantly different between enriched classes and regular classes.

With respect to motivational beliefs and engagement, analyses showed that in French classes, differences affected students' engagement ($F_{2,140} = 3{,}60$, $p<.05$) and the value assigned to the academic subject ($F_{2,140} = 3.04$, $p=.05$). In math, these beliefs involved the value assigned to the academic subject ($F_{2,139} = 27.75$, $p<.0001$). Once again, in all cases, differences revealed that Protic classes were at an advantage compared to other classes.

2. Relationships among variables relative to classroom organization and variables linked to the teaching-learning process

Initially, we examined correlations among the seventeen variables studied. These are shown in Table 2. A first glance at the correlations among variables in each block (instructional organization, learning strategies, needs, academic goals and motivational beliefs) suggests that certain groupings can be made. Indeed, in two of the blocks, the majority of correlations exceeded 0.50. Factorial analyses were then conducted for each block. With respect to the block of variables relating to instructional organization of the classroom, the analyse of principal components yielded a single factor explaining 62.6% of the variance in French classes and 68.4% in mathematics classes. With respect to the three variables included in the learning strategies block, the factorial analysis also indicated that the solution to a factor is the best factor alone explaining 72.8% and 74% of the variance. With respect to the four variables making up the needs block, it was divided into two factors explaining 76.8% and 81.5% of the variance. Belonging is associated with power, and freedom with fun. As for academic goals, correlations were weak. It was not deemed worthwhile, in either theoretical or empirical terms, to attempt to amalgamate them. New constructs will thus be used in initial regression analyses.

An examination of the rest of the grid shows that certain variables are fairly highly correlated with others. These are the three variables in the learning strategies block, as well as the fun and intrinsic value variables. It is observed as well that the instructional organization block is linked fairly closely to learning strategies and needs satisfaction.

In the second stage, regression analyses were conducted in order to describe the contribution of the four variables relating to instructional organization of the classroom to six constructs relating to students' perceptions. Examining Table 3, we note that the variables linked with classroom organization are linked to several constructs. Collaboration, investigation, innovation and individualization account for 43% and 45% of the variance in learning strategies in French and math. With respect to needs for belonging and power, as well as for freedom and fun, satisfaction of those needs is significantly linked to three of the four variables. Collaboration is the most closely linked to needs for belonging and power, while innovation and individualization are related to freedom and fun. Next, among students' academic goals, mastery goals are the most closely linked to organization variables: mainly individualization and investigation in French class and collaboration and investigation in math class. Lastly, identical analyses were conducted separately for Protic classes and other classes, and the results proved to be essentially the same as for all classes taken together.

3. Prediction of motivational beliefs and engagement

Table 4 shows the results of regression analyses of self-efficacy, value assigned to academic subject, and engagement. Self-efficacy is linked mainly to mastery goals and satisfaction of needs for belonging and power. For French classes, performance goals can be added. Intrinsic value is fairly closely linked to predictors, as witnessed by the 66% and 68% variances explained in French and math classes, respectively. The principal predictors are mastery goals, instructional organization of the classroom, and to a lesser extent, avoidance goals. On the other hand, it was in math classes that learning strategies are fairly closely linked to value assigned to academic subject. Lastly, engagement is more weakly linked to predictors. The largest share of variations of this variable is attributable to learning strategies adopted by students.

Table 5 shows analogous analyses, bringing out in detail the contributions made by each variable making up the constructs used in the preceding analyses. What emerges again is that self-regulation of learning and adoption of mastery goals are the most often significantly linked to self-efficacy, the value assigned to the academic subject, and students' engagement.

Discussion

Our primary research objective bore on differences between Protic, enriched and regular classes. Out of 17 comparisons in French classes, seven proved to be significant. In math classes, 14 out of 17 were significant. In most cases, it was Protic classes that showed themselves superior to the other two contexts, and there was no significant difference between regular classes and international education program classes. In French, instructional organization was characterized by more collaboration and more investigative assignments in Protic classes than in others. It was in these classes as well that students were more active in their knowledge construction, adopted fewer performance and avoidance goals, assigned greater value to the academic subject, and were more engaged in their studies. In math, organization of the Protic class was characterized by collaboration among students, a search for answers to questions they were asked. Their teachers were deemed to be more innovative and closer to their students. Individually, students in Protic classes said they adopted learning strategies that reflected their high-level intellectual skills: systematic processing of problems, active knowledge construction, and self-regulation of learning. The goals they set for themselves were rather those of mastery, performance or avoidance, and their needs were better satisfied. Lastly, they stood out from other students in a greater valorization of the subjects they studied.

Results such as these suggest, at any rate in the study we have described, that ITC-assisted project instruction is associated with a demonstration of attitudes, perceptions and behaviour that denotes a process of acquiring higher intellectual skills that goes well beyond the simple acquisition of new technical skills. As Laferrière, Breuleux and Bracewell (1999) put it so well, the advantages to be expected in the years following integration of ITCs into the classroom relate mainly to more in-depth learning of subjects and broadening of learning activities.

This study does not, however, make it possible to discern the sources of differences between Protic classes and others, aside from the impact of portable computers and project instruction. For example, student recruitment, the particular role of teachers, or the possibility of various uncontrollable effects could not be isolated from other variables. We must, however, accept the evidence that portable computers are valid tools only to the extent that teachers agree to alter their practices by bringing them closer to a constructivist philosophy that puts the student in charge of his or her learning. Among additional explanations, we might mention organization of work as an explanation of the gains observed in Protic classes. A study by Lee and Smith (1996) assessed three constructs measuring teachers' organization of work, i.e. their collective responsibility toward students' learning, cooperation between students and teachers, and control over working conditions in the classroom, and arrived at the conclusion that students were more successful and success more evenly shared when these conditions were provided.

Results of regression analyses proved to be essentially the same when related to Protic classes, regular classes or all classes, and hence we may conclude that the same cognitive and emotional processes were in play, interacting in every context. Differences between them lay rather in the levels of variables. Once these processes were activated, interrelationships among instructional organization, learning strategies, motivational beliefs and engagement were the same everywhere. The advantage held by Protic over other classes thus resided in the enhancement of students' learning conditions and levels.

Future studies should bear on analysis of the roles of teachers and learners in a learning context based on the socio-constructivist approach. We know the principal benefits of introducing technology rest on the changes in teachers' conceptions, which should lead to changes in their teaching strategies (Lin and Hsieh, 2001). The teacher's mediation work should become the main subject of future studies. Lastly, the fact that these new environments involve more responsibilities for students obliges us to be vigilant regarding the impact of students' learning styles on their academic success.

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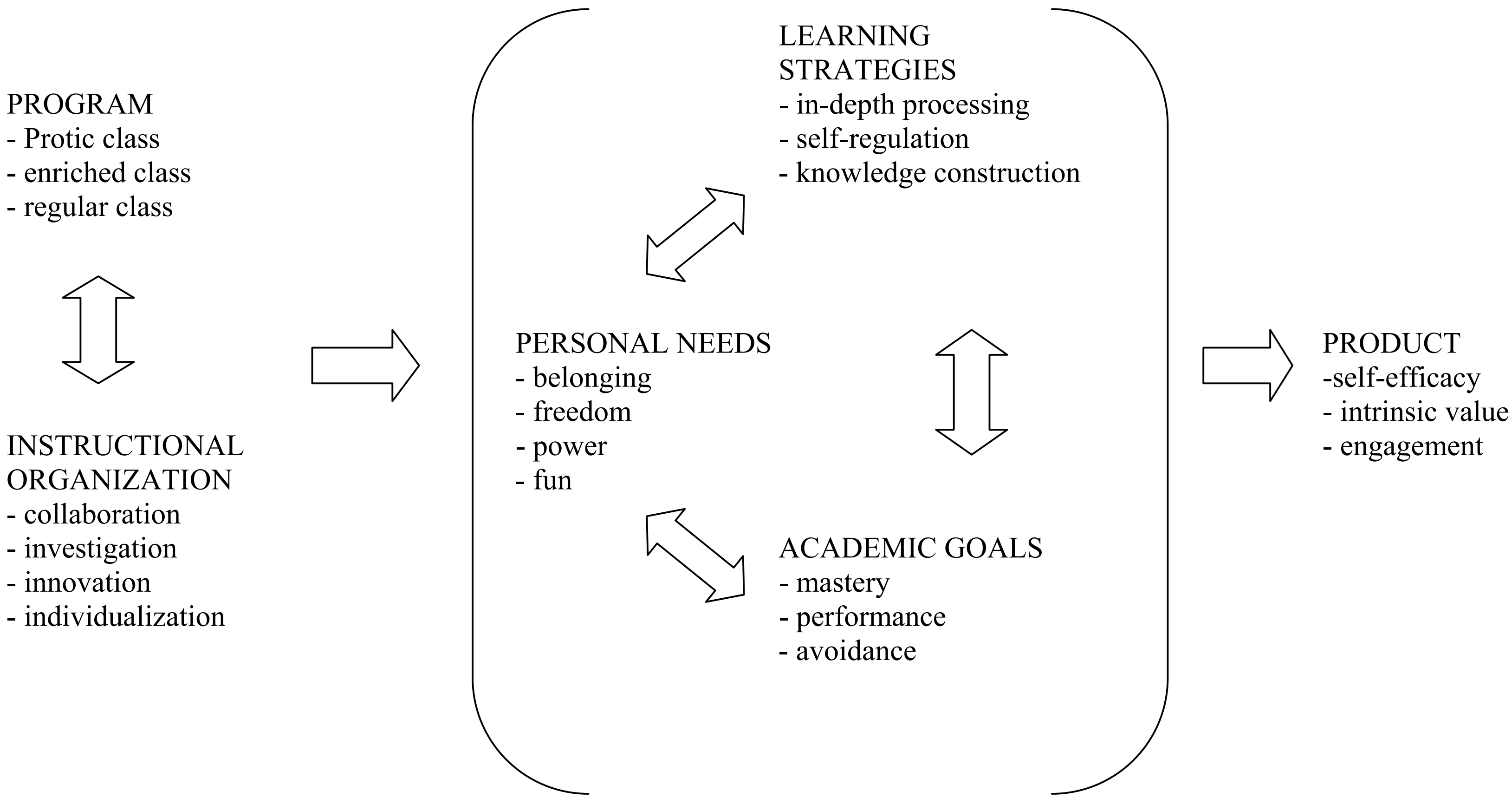

Fig. 1: Analytical model of relationships among instructional organization of the classroom, academic goals and learning strategies, motivational beliefs and students' engagement

Table 1
Averages and levels of significance of differences among variables, by instructional context

	French				Mathematics			
	Protic Class	Enriched Class	Regular Class	p	Protic Class	Enriched Class	Regular Class	p
Instructional organization								
COLLABORATION	3.48	3.12	2.80	.00	3.68	2.65	2.74	.00
INVESTIGATION	3.28	2.59	2.40	.00	3.51	2.49	2.27	.00
INNOVATION	3.28	3.26	3.12	.56	3.62	2.97	2.77	.00
INDIVIDUALIZ'T'N	3.13	3.11	2.87	.24	3.63	2.67	2.39	.00
Learning strategies								
IN-DEPTH PROC'G	3.22	2.90	3.00	.06	3.51	3.02	2.96	.00
KNOWL.CONSTR.	3.34	3.12	2.78	.01	3.59	2.90	2.82	.00
SELF-REGUL'N	3.58	3.41	3.39	.33	3.86	3.56	3.45	.02
Academic goals								
MASTERY	3.41	3.31	3.30	.80	3.90	3.21	3.17	.00
PERFORMANCE	2.42	2.48	2.79	.04	2.54	2.44	2.64	.48
AVOIDANCE	2.04	2.45	2.65	.00	1.87	2.32	2.73	.00
Satisfaction of needs								
BELONGING	3.58	3.49	3.29	.28	3.76	3.10	2.86	.00
FREEDOM	3.52	3.24	3.43	.19	3.80	3.20	3.02	.00
POWER	3.23	2.98	3.07	.36	3.42	2.57	2.73	.00
FUN	3.26	3.20	3.13	.78	3.96	2.73	2.61	.00
Motivational beliefs and engagement								
SELF-EFFICACY	3.68	3.48	3.54	.39	3.44	3.28	3.21	.07
INTRINSIC VALUE	3.67	3.36	3.34	.05	4.16	3.50	3.25	.00
ENGAGEMENT	3.58	3.22	3.22	.03	2.98	2.80	2.89	.09

Table 2
Averages, standard deviations and simple correlations among variables in study

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Collaboration	-	.65	.45	.35	.51	.31	.39	.47	.43	-.05	-.25	.41	.42	.55	.31	.48	.10
2. Investigation	.61	-	.51	.34	.33	.31	.32	.49	.48	.03	-.26	.50	.38	.53	.24	.49	.12
3. Innovation	.56	.52	-	.47	.39	.54	.33	.51	.47	.03	-.19	.35	.50	.47	.34	.47	.14
4. Individualization	.61	.61	.56	-	.31	.44	.35	.56	.48	.08	-.16	.35	.38	.46	.35	.45	.00
5. Belonging	.59	.37	.47	.40	-	.25	.60	.42	.35	.09	-.12	.29	.35	.34	.37	.36	-.06
6. Freedom	.43	.38	.58	.45	.28	-	.30	.44	.47	.16	-.25	.39	.50	.39	.31	.42	-.14
7. Power	.51	.37	.35	.32	.69	.25	-	.39	.48	.36	-.07	.44	.38	.42	.38	.34	.09
8. Fun	.63	.62	.65	.69	.49	.52	.43	-	.56	.02	-.15	.47	.36	.46	.29	.54	-.07
9. Mastery	.48	.45	.36	.40	.37	.43	.38	.38	-	.31	-.33	.75	.65	.63	.56	.79	.14
10. Performance	.16	.18	.14	.09	.26	.09	.36	.12	.30	-	.21	.30	.20	.20	.38	.15	.03
11. Avoidance	-.19	-.19	-.12	-.16	-.14	-.22	-.20	-.16	-.21	.21	-	-31.	-.46	-.25	-.18	-.39	.01
12. In-depth processing	.50	.55	.41	.47	.33	.50	.37	.48	.70	.27	-.21	-	.60	.65	.43	.68	.20
13. Self-regulation	.41	.29	.46	.39	.30	.58	.23	.39	.57	.15	-.25	.61	-	.61	.50	.58	.18
14. Knowledge constr.	.55	.54	.54	.58	.35	.49	.40	.58	.59	.19	-.24	.68	.54	-	.41	.56	.14
15. Self-efficacy	.31	.17	.25	.26	.36	.33	.31	.14	.53	.31	-.05	.42	.47	.30	-	.47	.03
16. Intrinsic value	.51	.48	.53	.46	.40	.50	.37	.47	.76	.17	-.38	.67	.66	.61	.47	-	.15
17. Engagement	.21	.08	.19	.27	.15	.21	.20	.16	.24	.10	.06	.25	.30	.21	.26	.24	-
Avg. in French	2.90	2.57	3.05	2.86	3.37	3.27	2.97	2.95	3.20	2.51	2.41	2.95	3.42	2.95	3.29	3.34	2.86
Standard deviation	0.88	0.92	0.77	0.85	0.83	0.78	0.84	1.03	0.88	0.74	0.80	0.71	0.72	0.88	0.50	0.77	0.46
Avg. in math	3.03	2.76	3.13	2.90	3.26	3.36	2.90	3.11	3.40	2.52	2.27	3.16	3.60	3.07	3.31	3.62	2.88
Standard deviation	0.85	0.93	0.75	0.94	0.92	0.78	0.93	1.08	0.89	0.76	0.88	0.67	0.78	0.86	0.52	0.75	0.42

Upper right side of table: results of French classes
Lower left side of table: results of math classes
Correlations higher than .20 are significant ($p < .01$).

Table 3
Regressions of variables linked to instructional organization, learning strategies, students' needs and academic goals (beta coefficients)

	Learning Strategies		Belonging and Power		Freedom and Fun		Mastery Goals		Performance Goals		Avoidance Goals	
Instructional Organization	Fren	Math	Fren	Math	Fren	Math	Fren	Math	Fren	Math	Fren	Math
Collaboration	.25	.38	.50	.60	.17	.20	.10	.48	.05	.09	-.14	-.12
Investigation	.55	.14	-.04	.00	.11	.13	.36	.24	.09	.14	-.26	-.19
Innovation	.19	.57	.23	.16	.44	.71	.19	.09	.01	.14	-.04	.02
Individualization	.32	.23	.17	-.02	.60	.40	.48	.07	.11	-.07	-.06	-.02
Adjusted R2	.43	.45	.30	.36	.52	.63	.35	.25	.02	.06	.06	.02

Significant beta coefficients ($p < .05$) are highlighted.

Table 4
Regressions of instructional organization of the classroom, learning strategies, needs and academic goals on students' motivational beliefs and engagement

	Personal effectiveness		Intrinsic value		Engagement	
	Fren	Math	Fren	Math	Fren	Math
Instructional organization	.09	.15	.21	.13	.23	.06
Learning strategies	.08	.14	.10	.43	.39	.28
Belonging and power	.19	.16	.02	.02	-.07	.11
Freedom and fun	-.05	-.05	.05	.05	-.12	.03
Mastery goals	.56	.55	.79	.75	.13	.06
Performance goals	.23	.10	-.05	-.03	-.08	-.06
Avoidance goals	-.03	.05	-.11	-.18	.13	.13
Adjusted R2	.37	.32	.66	.68	.12	.07

Significant beta coefficients ($p < .05$) are highlighted.

Table 5
Regressions of variables related to instructional organization of the classroom, learning strategies, needs and academic goals on students' motivational beliefs and engagement

	Personal effectiveness		Intrinsic value		Engagement	
	Fren	Math	Fren	Math	Fren	Math
Instructional organization						
Collaboration	.03	.04	.18	.00	.13	.10
Investigation	-.09	-.07	.00	.04	.04	-.13
Innovation	.03	-.04	.06	.23	.33	.00
Individualization	.08	.13	.05	-.02	.01	.28
Learning strategies						
Systematic processing	-.06	.01	.20	.10	.21	.06
Knowledge constr.	-.04	-.12	-.03	.02	-.08	-.06
Self-regulation	.23	.30	.00	.34	.30	.22
Needs						
Belonging	.18	.25	.11	.03	-.03	-.07
Power	-.03	.03	-.06	.00	.14	.10
Freedom	-.03	.11	-.02	-.05	-.15	.04
Fun	-.07	-.07	.09	.02	-.18	-.07
Academic goals						
Mastery	.56	.55	.79	.75	.06	.09
Performance	.23	.12	.00	-.03	-.10	-.04
Avoidance	.00	.05	-.09	-.19	.14	.15
Adjusted R2	.66	.39	.66	.69	.16	.09

Significant beta coefficients ($p < .05$) are highlighted.