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Attempting to Develop Secondary Student's Interest for Science and Technology Through an In-Service Teacher Training Initiative Based on the Principles of the Learning Community

Patrice Potvin

Université du Québec à Montréal, Canada

Abdelkrim Hasni

Université de Sherbrooke, Canada

Ousmane Sy

Université du Québec à Trois-Rivières, Canada

Abstract: This article presents the results of a quasi-experimental research that has been conducted by the (*Infrastructure of the authors*) for two years. This research aimed at increasing student's interest for science and technology (ST) by enhanced pedagogical interventions, designed by their teachers in the context of a learning community. It also aimed at measuring this possible increase. Results show that three of the four intervention types (scientific inquiry, context-based and project-based learning) had positive effects of various strengths on students' interest, but that collaborative teaching did not. Hypotheses to explain these results and recommendations are formulated.

Keywords: Interest; Science and technology; Learning community; Scientific inquiry; Context-based learning; Collaborative teaching; Project-based learning.

Introduction

Students' interest for science and technology (ST): a critical issue

While often viewed as secondary in contrast to expected learning, students' interest in an academic subject or discipline is not without consequence. Indeed, and not surprisingly, it has frequently been shown that interested students learn more and have better achievement (Cavas, 2011; Gottfried, Marcoulides, Gottfried and Oliver, 2009; Pan and Gauvain, 2012; Singh, Granville and Dika, 2002). The Québec Education Program also recognizes the importance of interest with respect to studies and mentions its role explicitly and regularly. For example, the Science and Technology Program in secondary cycle one education (2004), explains that

> "Interest in science and technology can be developed in various ways, and it is the school's responsibility to explore these different avenues" (p. 268); and that "These activities involve requirements as well as challenges and bring a certain measure of satisfaction that enables students to discover their interests and aptitudes and to develop them, thereby helping them chart their academic and career path" (p. 270).

Indeed, in addition to learning, interest for ST has the effect of promoting further studies on the subject and ultimately ensuring the future of the ST-related careers (Reid and Skryabina, 2002), which is key to the growth of industrialized societies and the development of a scientific and technological culture.

Yet, students' interest for ST is currently viewed as problematic. Its decline has in fact been recorded across all OECD countries. In universities, whose populations have exploded over the past decades, enrolment in science and engineering has reached a plateau and sometimes even declined (OECD, 2005, 2006). Quebec is no exception to this trend and a recent study showed that, like other countries (Barmby, Kind and Jones, 2008; Osborne, Simon and Collin, 2003; Turner and Ireson, 2014), the province shows a decline in the interest of its students from the fifth year of primary education through the fifth year of secondary education (Potvin & Hasni, 2014a). Since the level of scientific and technological culture affects not only the labour market but life in society as a whole through consumption and the exercise of a healthy and educated democracy, it is easy to understand why developing interest in ST in school is a critical issue.

Teaching Practices Supporting Interest Development

Among the factors that are likely to influence interest, some are out of the school's control, such as gender or socio-economic status. However, a preliminary literature review of 228 research articles (Potvin & Hasni, 2014b) has revealed the very important role that schools can play in developing interest; particularly the teachers, their personality and their ability to generate enthusiasm; but also, and maybe more importantly, the practices they apply, with the preferred ones generally being those that get their students actively involved (p. 14). The large number of research studies focusing on the effects of certain types or methods of intervention suggest that researchers have detected an interesting approach to the problem. And indeed, pretty much across the board, declining interest is attributed to the school (Osborne et al., 2003) while paradoxically, teaching practices are simultaneously presented as the best hope to remedy the situation (George, 2006).

Continued Teacher Education as a Vector for Improving Practices

Once teachers have completed their initial training, only continuing education remains to support them in their professional development. While it is generally possible to count on teachers' ability to stay abreast of new advances, the fact remains that continuing education is a precious opportunity to take the time to pause and think about one's practice, to infuse it with research-based subject material knowledge, to develop innovative teaching strategies, and to benefit from the experiential knowledge of one's peers.

Moreover, continuing education programs that avoid "top-down" formulas and instead follow the learning community model are seen as the best way to reach these objectives. A learning community would thus allow innovative teaching strategies, based on certain types of interventions likely to be effective, to be co-developed by teachers participating in the learning community and subsequently tested directly on their students to ultimately reach the objectives explicitly set by the community. Given…

1. the importance of cultivating interest for ST among students;
2. that changes in teaching practices can influence interest; and
3. that the learning community is probably the training method that ought to be pursued in

order to promote improvements in the practices;

our research question is the following: (Q1) Can secondary school students' interest for ST be increased through activities that follow the method of the learning community, and in which their teachers are involved? We also ask (Q2) whether it is possible to measure the effects of such training.

Conceptual Framework

The Concept of Interest and its Different Dimensions

The appeal that ST holds for students has been widely studied in education (Renninger and Hidi, 2011). Many researchers have attempted to understand the meaning and intensity of this relationship and to measure it through the development or use of different constructs, or concepts, such as attitude, motivation, *self-concept*, *enjoyment*, *preference* (Christidou, 2011), etc.

These different constructs have focused on multiple dimensions of interest. Thus, motivation looks at the *reasons* (motives) that underlie and nurture the relationship between a subject and a particular object (Areepattamannil, Freeman and Klinger, 2011); *self-concept* focuses on a person's evaluation of their performance in the subject (Haussler and Hoffmann, 2002), while *enjoyment* measures the enjoyment felt when practising such or such activity, etc.

Many questionnaires have been developed to attempt to produce reliable measures of such constructs, and have been made available by their authors through their publications. It would be impossible to make an inventory of them here, but we can nonetheless affirm that the most common questionnaires, by decreasing order of importance, focus on attitude, motivation and interest (Potvin & Hasni, 2014b). We can also affirm that the most studied aspects, and the most frequently represented in these constructs, are the cognitive aspects (what I understand of it), affective aspects (what I feel), behavioural aspects (what I make of it or what I wish to do with it) and the "value" that we ascribe to the subject or activity: "is it important to me? useful?") (Hasni & Potvin, 2015). These dimensions and these aspects, which play a role in the collective effort to define, understand and measure the general idea of "interest," are conceptual compromises, but they also make up the relationship that exists between a subject and an object of knowledge or an activity. We can also be specific about this interest, depending on the objectives being pursued, by associating it generally albeit imperfectly, with specific objects or contexts, such as *ST* (more general) or *ST such as it is experienced in school* (more specific and context-based).

Several dimensions of interest were previously studied by our team during a questionnaire-based inquiry involving close to 3,000 students in primary and secondary school (Hasni & Potvin, 2015; Potvin & Hasni, 2014a). During discussions in the course of the work, it was deemed that certain factors, such as "*interest* for ST in school," "*self-concept* in ST," as well as "*preference*" were among the most likely to record changes following the implementation of new teaching practices. They were thus selected for this research study.

According to the Hidi model (2006), which this research study follows, similar factors are presumed to be able to change as long as positive educational experiences that are able to trigger situational interest (i.e., short-lived interest (even though likely to become lasting), generated by favourable circumstances), are triggered often and/or occur repeatedly over a rather long period. According to the model, it is thus possible to influence individual interest through the intervention of "interesting" educational activities.

Intervention Types Likely to Increase Students' Interest for ST

Our literature review (Potvin & Hasni, 2014b) allowed us to identify, define and summarize several types of teaching interventions more likely to generate interest, according to the research. These were also the subject of earlier synthetic publications (Potvin & Hasni, 2013, Potvin, 2018). Among all of those types of interventions, four were deemed to be sufficiently operational in the context of continuing education. They were thus selected to underpin this continuing education. We provide here an overview of their label, definition and main components. In doing so, we are laying out the content of the learning community training.

1. *Scientific inquiry*: Scientific inquiry refers to the processes by which it is possible to build a rational understanding of the world around us (based on facts and proof) and communicate that understanding in the form of scientific statements. (concepts, models, etc.) (Hasni, Belletête & Potvin, 2018)
   a. Presence of a problem that makes sense to students; presents a reasonable challenge whose response requires the use of scientific inquiry;
   b. Presence of specific, well-formulated and realistic question(s) or hypothesis(es);
   c. Proposal and validation of a research protocol;
   d. Completion of the protocol or research using available data;
   e. Data organization and analysis;
   f. Data interpretation; understanding of the phenomena and formulation of scientific statements.

2. *Context-based learning*: Pedagogical methodology that aims to ground learning on a physical, social, economic or other reality.
   a. Context-based learning is all the more successful as the grounding on reality is deeper and more frequent;
   b. It is essential that the scope of the learning go beyond the school walls and its ordinary requirements (e.g.: passing the exam).

3. *Collaborative teaching*: Is an active process whereby the learner works on building his/her knowledge. The educator plays the role of learning facilitator while the group participates as a source of information, as a motivating agent, as a means to provide mutual help and support and as a privileged place of interaction for the collective construction of knowledge. This process recognizes the individual and reflexive nature of learning.
   a. Presence of "incentives" to collaboration;
   b. Positive interdependence;
   c. Clearly defined and shared learning objectives to be reached in ST;
   d. Clearly and fairly distributed responsibilities;
   e. Importance of quickly achieving team "success."

4. *Project-based learning*: The project aims to resolve a problem grounded on reality and leads to a product intended for actual or presumed use.
   a. Open-ended, complex and context-based problem;
   b. Completion of an artifact as the result of resolving the selected problem;
   c. Learning and use of conceptual knowledge in ST.

These types of interventions were also combined, during training, with short lists of specific challenges that usually occur when these interventions are implemented, and possible drifts. For example, it is important that context-based learning not be solely achieved using a series of historical capsules; project-based learning cannot simply be the creation of a technical object based on a drawing; collaborative teaching cannot limit itself to teamwork; and scientific inquiry cannot be limited to following a recipe, such as recreating a famous scientific experiment, nor can it consist in nothing more than practical work.

These are the four intervention types for which training was provided in the context of a learning community focusing on their definition, components, challenges and frequent drifts.

The Learning Community as Training Method

“Several authors increasingly see professional teacher development as a process comprised not only of initial training and continuing education, but also of peer input and personal reflexivity in other personal or professional situations” (Daele and Charlier, 2006, p. 90). In the face of such challenges, *practice-based communities* (Chanier and Cartier, 2006; Lave and Wenger, 1991), *professional learning communities* (Labelle, Freiman, Barrette, Cormier and Doucet, 2014; Schaap et al., 2019) or more generally *learning communities*, have become preferred training methods in the realm of continued teacher education (Labelle et al., 2014). Couture (2012), in presenting a community of ST teachers who engage in “practice adjustments,” uses the terms used by Dionne, Lemyre and Savoie-Zajc (2010) when she defines it as a “a collective and flexible training and research method promoting the development of the teaching practice.”

Although such complex methods (Vossen et al., 2019) can be widely found in different forms, some authors have nonetheless attempted to define their invariable attributes. Thus, for example, according to Bielaczyc and Collins (1999), eight dimensions must be present to create a productive learning community: a common and shared goal; meaningful activities; an instructor who acts as a guide/group leader; participants who are seen as resources; who are occasionally put at the centre of the activity; a message that is geared toward co-building; a shared subject of knowledge; and artifacts that are created collaboratively.

Those are the precise criteria that the researchers used in this study to design the training curriculum.

Methodology

The Learning Community

A learning community of 31 teachers was created in 2012-13 and another of 29 teachers in 2013-14, both of which operated similarly. Some teachers participated both years. These teachers were recruited from public school board partners of *Research Chair on youth’s interest in science and technology* (CRIJEST) by educational consultants responsible for ST.

The goals of this training were to

1. train teachers on the variables likely to stimulate students’ interest for ST based on the available research data (meta-analyses), and help teachers translate those variables into teaching interventions;
2. give teachers the opportunity to test the effect of these interest interventions in an actual context and to measure this effect in order to confirm the effectiveness of the interventions, if applicable;

3. provide teachers the opportunity to share their experiences with teaching methods promoting interest in science and technology within a learning community environment comprised of their peers, educational consultants, and researchers; and
4. provide education researchers with data on intervention effectiveness, whose results they could then share with the community as a whole.

The teachers were given leave by their school boards to participate in this activity over six days spread from the beginning of the school year through early February. After an information session on the objectives and workings (Phase 1), they underwent a day of training and discussion focusing on the types of interventions likely to better promote their students' interest, according to the research, and the data collection methods (Phase 2). During this phase, the teachers administered the pretest questionnaires to the students participating in the study (Phase 3 [see below for more info on the administration of this test]). Each teacher then selected a type of intervention among the four available and continued, over the next three days, with the development of an "enhanced" teaching intervention based on what they would normally do with their students, that is to say, using the same educational objectives as usual but transforming their planning such as to best and most frequently include the components of the type of intervention selected for the period in question. This development (followed by a clarification session) was done in teams with the support of peers, educational consultants and researchers. A fourth day of planning, hosted by the school boards and managed by the educational consultants, was then added to the calendar (phase 4). These activities were accompanied by mini-seminars where teachers presented the fruit of their reflections and of their pedagogical work with the learning community.

Once the planning was completed, the experimental phase (Phase 5) took place over the course of the months following February. During this phase, which lasted 5 to 10 consecutive teaching periods, the participants taught a group of their students as usual, and another group using the "enhanced" intervention, thereby creating respective "control" and "experimental" groups. The number and names of students in either group remained at the teachers' discretion. The latter were instructed to teach the same concepts concurrently and to pursue the same learning objectives in both groups (albeit using different interventions), and to attempt to highlight the differences related to the selected variable, but without any risk of doing damage to the control group. Thus, for example, a teacher who chose to teach the properties of matter over seven periods and selected the "scientific inquiry" type of intervention would teach those seven periods as usual with the control group, while also modifying his or her teaching of the properties of matter for the experimental group by "injecting" the elements of the scientific inquiry process over the course of the seven periods. Figure 1, which was used to illustrate the workings of the research to the participants, shows the different phases of the training and of the experimental phase, with the experimental group identified by small black stars.

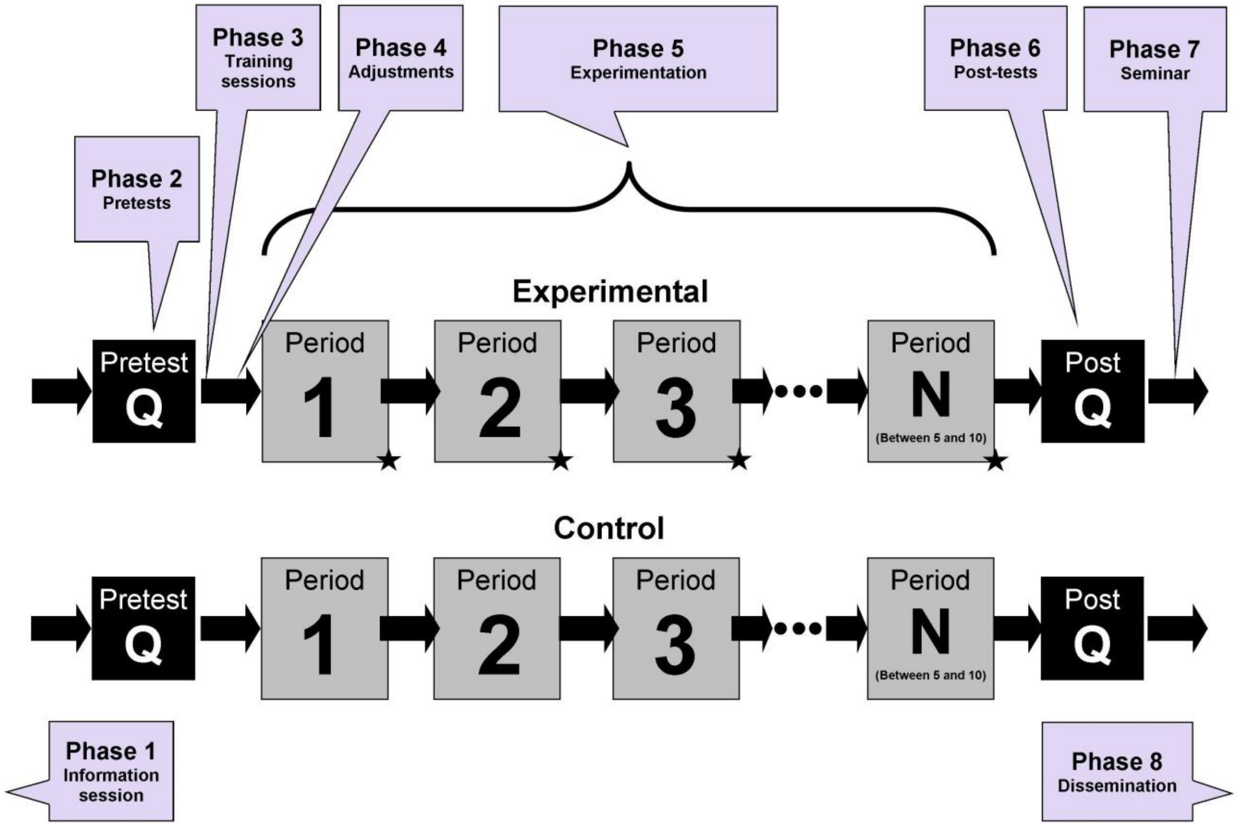

Figure 1. Learning community activities and experiment flow diagram

After the experiment came Phase 6, where the same students were given the post-test questionnaires, followed by the final seminar day (Phase 7) at the end of the school year, during which the teachers reported on and discussed their experiences related to their intervention in the classroom through oral presentations and visual aids. Phase 8 concerned certain scheduled initiatives allowing the researchers and teachers to present the results in seminars and conferences.

Dependent Variable: Interest and the Instrument Used to Measure it

The pretest questionnaire and the post-test questionnaire were both based on the *CRIJEST* general questionnaire, which was designed and validated earlier. The latter, which included 139 questions distributed over two sub-questionnaires (one for students with last names beginning with letters A through J, the other for students with last names K-Z), explored numerous dimensions of individual interest. For this analysis, we will retain the following dimensions:

1. "*interest for ST in school*," which represents the sum of scores (sometimes reversed when the item is negative) obtained using 5 Likert-type items on 5 levels (Cronbach's alpha = 0.89; examples of items: "ST at school is so dull," "We should spend more time doing ST at school.") For the purposes of this article, we will use the word *interest,* in italics, to distinguish this variable, which is more specific and related to the school activity, from "general" interest, no italics, which will be

considered in the broad sense and will include not only *interest* (for ST in school) but also the two other variables studied;

2. "*Self-concept*," which is the sum of 6 items (Cronbach's alpha = 0.82; examples: "Compared to my friends, I understand ST [With great difficulty → Very easily]," "When I do not understand something in ST, I get easily discouraged");
3. "*Preference*," which is the sum of 6 items (Cronbach's alpha = 0.71; examples: "in school, I prefer ST to art").

For information on the other items used, we refer the reader to our earlier publications, which provide detailed explanations of these items (*Hasni & Potvin*, 2015; *Potvin & Hasni*, 2014a).

The teachers themselves administered the pretests and post-tests. They read the instructions aloud, and allowed about 30 minutes to complete. The copies were gathered and forwarded to the university for analysis.

Subjects

Only students of teachers who followed the "control/experimental groups" research protocol were considered in the study. A total of 1,277 subjects from different levels of secondary education (ages 12 to 16) spread over 21 participating teachers (each one teaching only one specific level) provided a consent form and completely or partially answered the questionnaires. They also participated in one of the developed teaching procedures, either in the experimental groups or in the control groups. They were recruited by the participating teachers and in accordance with the ethics protocol obtained from the university.

Hypothesis

The hypothesis put forth in this research study is obviously that the planned training will have positive effects on the individual interest of students, as measured by the three dimensions identified above. However, it is not impossible that the opposite hypothesis will prevail. Indeed, other comparable research studies have noted that in certain cases where innovative teaching strategies resulted in actual learning, decreased motivation was nonetheless observed (Shachar and Fischer, 2004).

Results

Interest

All gains were calculated by substracting pretest results from post-test ones. Table 1 shows the t-test results for gains in *interest* for the control group and the experimental group. There is great variation in the number of subjects considered because that number depends on the number of student groups implicated by the teacher, the number of consent forms actually obtained and the number of students who had to answer questions or not (depending on the A-J versions or K-Z versions of the questionnaires, because the questionnaires did not all contain all the questions). Teacher data comprising fewer than 20 usable student questionnaires were excluded. The "*p*" column (2-tailed) shows the significance of the difference. The "*d*" column shows the effect size. In this column, the data supporting the hypothesis that the experimental groups performed better than the control groups and having an effect size greater than 0.2 are highlighted in green. We added an asterisk when 0.5<*d*<0.8 and two asterisks when (*d*>0.8). *d* values under -0.2 (supporting the opposite hypothesis) are highlighted in red and an asterisk was added for cases where -0.8<*d*<-0.5 (two asterisks when *d*<-0.8). All of the following tables are presented in the same way. The names of the teachers are fictional.

Table 1.
T-test results for gains in interest

Intervention type	Teacher pseudonym	Group	N	M	ET	Standard error	t	*p*	*d*
Scientific inquiry	Jeanne	Control	29	-3.34	4.498	0.835	-2.419	**.019***	071*
		Experimental	26	-0.15	5.282	1.036			
	Paul	Control	5	-3.00	8.000	3.578	-0.445	.662	0.18
		Experimental	15	-1.53	5.842	1.508			
	Émile	Control	8	-1.25	2.915	1.031	-1.385	.180	0.70*
		Experimental	15	0.80	3.590	0.927			
Context-based learning	Valérie	Control	9	-1.22	3.270	1.090	-0.255	.802	0.18
		Experimental	11	-0.64	6.201	1.870			
	Marie	Control	12	-1.92	6.230	1.798	-0.226	.823	0.06
		Experimental	24	-1.54	3.741	0.764			
	Marcel	Control	19	-1.47	3.204	0.735	-0.606	.548	0.26
		Experimental	26	-0.65	5.215	1.023			
	Vicky	Control	17	-0.47	4.002	0.971	0.589	.561	-0.26
		Experimental	10	-1.50	4.994	1.579			
	Guillaume	Control	8	-1.00	5.014	1.773	0.165	.871	-0.07
		Experimental	12	-1.33	4.008	1.157			
Collaborative learning	Laurence	Control	21	0.716	4.970	1.085	0.608	.546	-0.19
		Experimental	22	-0.235	5.170	1.103			
	Grégoire	Control	30	1.67	5.726	1.045	0.760	.451	-0.10
		Experimental	27	0.70	3.429	0.660			
	Éléonore	Control	16	0.31	5.173	1.293	0.312	.758	-0.16
		Experimental	6	-0.50	6.156	2.513			
	Marianne	Control	11	2.00	4.195	1.265	2.956	**.007***	-1.03**
		Experimental	15	-2.33	3.288	0.849			
	Félix	Control	3	-1.00	1.000	0.577	0.609	.550	-2.35**
		Experimental	17	-3.35	6.538	1.586			
	Roseline	Control	12	-0.42	4.188	1.209	-0.597	.558	0.31
		Experimental	8	0.88	5.489	1.941			
Project-based learning	Nancy	Control	9	-3.89	3.756	1.252	-1.032	.316	0.55*
		Experimental	11	-1.82	4.956	1.494			
	Zackary	Control	26	-3.04	5.695	1.117	-2.745	**.008***	0.68*
		Experimental	27	0.81	4.472	0.861			

Table 1 results appear to show positive (*d*s higher than 0.5) results for 6 of the 16 pairs of groups, mostly concentrated in the “scientific inquiry” and “project based learning” categories, but also three negative results (with two rather strongly negative ones), concentrated in the collaborative learning category of intervention.

Self-Concept

Table 2 presents the t-test results for gains in *self-concept*.

Table 2.
T-test results for gains in self-concept

Intervention type	Teacher pseudonym	Group	N	M	ET	Standard error	t	*p*	*d*
Scientific inquiry	Jeanne	Control	55	-0.09	3.471	0.468	-0.597	.552	0.10
		Experimental	59	0.25	2.676	0.348			
	Paul	Control	14	-0.57	3.081	0.824	0.369	.714	-0.17
		Experimental	26	-1.08	4.578	0.898			
	Émile	Control	21	-0.43	2.638	0.576	-0.614	.542	0.16
		Experimental	29	0.00	2.283	0.424			
	Martin	Control	19	-0.47	2.389	0.548	-1.437	.161	0.56*
		Experimental	14	0.86	2.931	0.783			
	Steve	Control	13	0.31	3.038	0.843	0.046	.964	-0.01
		Experimental	15	0.27	1.580	0.408			
Context-based learning	Valérie	Control	19	0.11	3.089	0.709	-0.278	.782	0.10
		Experimental	19	0.42	3.863	0.886			
	Marie	Control	29	-1.52	3.055	0.567	-1.380	.172	0.30
		Experimental	46	-0.59	2.705	0.399			
	Marcel	Control	19	-0.53	3.389	0.777	-0.664	.510	0.21
		Experimental	27	0.19	3.701	0.712			
	Vicky	Control	27	0.63	2.356	0.453	1.709	.094	-0.47
		Experimental	21	-0.48	2.040	0.445			
	Guillaume	Control	23	-0.17	2.188	0.456	-0.019	.985	0.00
		Experimental	25	-0.16	2.925	0.585			
Collaborative learning	Laurence	Control	47	1.21	2.956	0.431	2.463	**.016***	-0.45
		Experimental	42	-0.12	1.990	0.307			
	Lorie	Control	11	1.73	1.954	0.589	-0.234	.817	0.14
		Experimental	13	2.00	3.416	0.947			
	Grégoire	Control	59	-0.73	2.766	0.360	-0.677	.500	0.12
		Experimental	62	-0.40	2.525	0.321			
	Geneviève	Control	12	-0.08	1.564	0.452	0.396	.694	-0.33
		Experimental	25	-0.60	4.359	0.872			
	Éléonore	Control	27	0.74	3.675	0.707	0.255	.800	-0.07
		Experimental	18	0.50	1.917	0.452			
	Marianne	Control	20	-0.45	2.089	0.467	1.688	.098	-0.52*
		Experimental	28	-1.54	2.269	0.429			
	Félix	Control	11	0.36	3.749	1.130	0.536	.596	-0.14
		Experimental	24	-0.17	2.120	0.433			
	Roseline	Control	26	1.23	2.355	0.462	1.297	.201	-0.39
		Experimental	25	0.32	2.657	0.531			
Project-based learning	Nancy	Control	20	0.05	2.837	0.634	0.748	.459	-0.26
		Experimental	26	-0.69	3.674	0.721			
	Zackary	Control	49	0.65	2.758	0.394	1.766	.080	-0.33
		Experimental	59	-0.27	2.664	0.347			
	Julien	Control	16	-0.25	2.817	0.704	-2.389	**.022***	0.78*
		Experimental	22	1.95	2.803	0.598			

Results that are presented in Table 2 do not appear to be as strong as the ones about *interest* (Table 1). Indeed, they are less homogeneous from one mode of intervention to the other and reach significance thresholds less often, maybe except in the case of collaborative learning, in which negative results appear more often (near the *d*<-0.5 threshold). We can also record robust and significant results at least once in *scientific inquiy* as well as in *project-based learning*.

Preference

Table 3 presents the t-test results for gains in *preference*. Stronger positive values indicate a higher preference for ST compared to other academic subjects. Gains in *preference* (Table 3) are also a bit more difficult to interpret than the ones of Table 1. No clear and significant trend can be identified, except maybe for *Emile* and *Julien*, who recorded more positive preference gains in their experimental groups. These two teachers had already recorded positive gains for other variables (*Julien* for *self-concept* and *Emile* for *interest*, suggesting that they were probably able to implement the interventions with more success or coherence, or with more intensity (then allowing to record significant differences). We can also notice that *collaborative learning* has, this time, recorded more positive results on *preference* than other modes of intervention (however without reaching significance thresholds).

Table 3.
T-test results for gains in preference

Intervention type	Teacher pseudonym	Group	N	M	ET	Standard error	t	*p*	*d*
Scientific inquiry	Jeanne	Control	23	-0.70	6.145	1.281	0.303	.764	-0.08
		Experimental	21	-1.19	4.479	0.977			
	Émile	Control	11	-1.91	2.982	0.899	-1.836	.079	0.91**
		Experimental	14	0.79	4.080	1.090			
Context-based learning	Marie	Control	17	-2.47	5.269	1.278	-0.792	.433	0.20
		Experimental	23	-1.39	3.340	0.697			
	Marcel	Control	9	-0.56	4.035	1.345	0.275	.786	-0.13
		Experimental	12	-1.08	4.562	1.317			
	Guillaume	Control	12	-1.58	3.502	1.011	-0.705	.488	0.31
		Experimental	12	-0.50	4.011	1.158			
Collaborative learning	Laurence	Control	23	0.22	4.738	0.988	1.151	.258	-0.38
		Experimental	15	-1.60	4.793	1.238			
	Grégoire	Control	26	0.62	4.428	0.868	0.260	.796	-0.07
		Experimental	32	0.31	4.403	0.778			
	Éléonore	Control	10	-0.90	4.433	1.402	-1.075	.296	0.43
		Experimental	11	1.00	3.661	1.104			
	Marianne	Control	8	-2.25	2.765	0.977	-0.832	.416	0.75*
		Experimental	12	-0.17	6.658	1.922			
	Roseline	Control	12	-1.92	9.180	2.650	-1.453	.159	0.42
		Experimental	14	1.93	3.496	0.934			
Project-based learning	Nancy	Control	13	0.46	4.409	1.223	-0.223	.825	0.11
		Experimental	15	0.93	6.431	1.660			
	Zackary	Control	20	1.20	4.991	1.116	1.870	.068	-0.45
		Experimental	29	-1.03	3.386	0.629			
	Julien	Control	10	-2.00	4.784	1.513	-1.907	.071	0.63*
		Experimental	12	1.00	2.412	0.696			

General Analysis

Table 4 presents the t-test results for all subjects for each dimension, by intervention type.

This table allows a better and stronger interpretation of the general effects of the four modes of intervention on each of the tested variables, becauses it adds up all groups and participants, when possible, regardless of the results they got in previous analyses (whether they be positive or negative). These general results do not seem to contradict previous tables because they suggest that two modes of intervention have significant and positive effect on students' individual *interest*. They are *scientific inquiry* and *project-based learning*. We can also see that collaborative learning has recorded *negative* while non-significant effects on *interest* and *self-concept*. These results will now be further discussed.

Table 4.
T-test results for the totals of each factor, by intervention type

Intervention type	Dimension	Group	N	M	ET	Standard error	t	*p*	*d*
Scientific inquiry	*Interest*	Control	53	-2.57	4.834	0.664	-2.834	**.005***	0.50*
		Experimental	82	-0.15	4.851	0.536			
	Self-concept	Control	128	-0.27	3.042	0.269	-0.535	.593	0.07
		Experimental	154	-0.07	3.027	0.244			
	Preference	Control	63	-1.43	5.167	0.651	-0.974	.332	0.16
		Experimental	63	-0.62	4.105	0.517			
Context-based learning	*Interest*	Control	77	-1.23	4.343	0.495	-0.175	.861	0.03
		Experimental	83	-1.11	4.688	0.515			
	Self-concept	Control	136	-0.26	2.891	0.248	-0.173	.863	0.02
		Experimental	138	-0.20	3.035	0.258			
	Preference	Control	62	-1.23	4.546	0.577	-0.562	.575	0.10
		Experimental	62	-0.79	4.074	0.517			
Collaborative learning	*Interest*	Control	104	0.95	4.937	0.484	2.215	**.028***	-0.30
		Experimental	115	-0.54	5.009	0.467			
	Self-concept	Control	213	0.37	2.904	0.199	2.175	**.030***	-0.20
		Experimental	237	-0.21	2.728	0.177			
	Preference	Control	92	-0.17	5.259	0.548	-0.446	.656	0.06
		Experimental	106	0.15	4.985	0.484			
Project-based learning	*Interest*	Control	47	-2.34	5.160	0.753	-3.066	**.003***	0.54*
		Experimental	59	0.46	4.236	0.551			
	Self-concept	Control	92	0.48	2.736	0.285	0.848	.397	-0.13
		Experimental	119	0.13	3.053	0.280			
	Preference	Control	44	0.16	4.803	0.724	0.310	.757	-0.06
		Experimental	59	-0.12	4.251	0.553			

Discussion

Let us note from the outset that the expression "significant" refers to the usual standard, for which *p*<.05. When we talk of a "large," "medium" or "small" effect, we are still referring here to the standards defined by Cohen (1988), for whom effect sizes falling between 0.2 and 0.5 (or between -0.2 and -0.5) are labelled "small"; values between 0.5 and 0.8 (or between -0.5 and -0.8) are labelled "medium"; and values beyond 0.8 (or less than -0.8) are labelled as "large." Results presenting effect sizes falling between -0.2 and 0.2 are not considered "significant" and thus will not be discussed here.

General Remarks

The first observation concerns the large majority of the measured variations, both in *experimental* groups and *control* groups, and what they show regarding declines. Indeed, out of 122 variations presented, we count 78 declines. We will state here two explanatory hypotheses: (1) either students' interest could be considered to be "naturally" declining during the secondary education period (Potvin & Hasni, 2014a), and consequently, that a more reasonable or urgent ambition than to promote interest in secondary education would consist in slowing down its decline; (2) or the fact of taking a post-test or informing persons that they were taking part in a research study might have had a negative effect on students, or on the participating teachers, through their effective actions. Either way, we can reasonably imagine that these effects are probably the same for all groups, which therefore does not threaten the value of our comparative study *a priori*.

A second general observation refers to the relatively high and varied standard deviations. They suggest that measuring interest remains a rather difficult endeavour and that this variable remains volatile, even noisy, and difficult to measure robustly. Nonetheless, we can observe consistent trends with respect to the comparison between the groups.

Comparison Between Control Groups and Experimental Groups

Scientific inquiry. All of the teachers who chose this type of intervention were able to produce, according to Table 4, positive and significant effects – of medium effect – on their students' *interest* when compared to the gains made in the control groups. However, we do not observe any change related to the other two measured dimensions, namely *self-concept* and relative preference.

When we perform a detailed analysis (Table 1), we observe that two of the three teachers under study who chose this type of intervention were able to produce medium positive effects on their students' *interest* even though only one of the two results has statistical significance. Another of these teachers was able to produce a positive effect (medium) on their students' *self-concept* and another (one of the two who had already achieved greater *interest*) achieved a large effect (nonsignificant, however, even though coming closer to the threshold [p=.079]), for *preference*. Overall, we find no noticeable negative result for this type of intervention but instead several very positive results including some that are significant. Consequently, we believe that these data allow us to support the hypothesis that the learning community helped increase the *interest* of the students whose teachers chose scientific inquiry as their intervention type in their innovative teaching strategies.

Context-Based Learning. Here the results are much less unequivocal. An overall review of the teachers who chose this type of intervention (Table 4) yields no conclusive result. Some differences appear, however, when we consider the teachers individually. Two of them obtained (nonsignificant) contradictory results for *interest* (Table 1); two others obtained positive results and another a negative result for *self-concept* (Table 2); and two others obtained positive results for *preference* (Table 3) (all "small effect" and all nonsignificant). We should note that unsurprisingly, in three cases, the results for the different dimensions for the same teacher went the same way. For example, interest and self-concept in Marcel's students increased while for Vicky's students, interest for both of those dimensions declined.

We can attempt to explain these divergent results from the fact that the definition and main components used during the training were broader and less explicit than for the other components, which may have resulted in one teacher interpreting context-based learning differently than another teacher and consequently, the classes were run in ways that varied substantially. This hypothesis is supported by teacher exchanges during training sessions and the reflexive feedback. Overall, we note more noticeable positive effects than negative effects, but none is statistically significant and none has an effect beyond a “small” effect.

Collaborative Teaching. Here, a majority of the results run counter to the hypothesis that experimental groups would record better results than control groups. Overall (Table 4), we note significant negative results, although of “small” effect, not only for *interest*, but also for *self-concept* for all students whose teachers chose this type of intervention. Upon closer observation, we note two teachers whose “enhanced” interventions produced “large” magnitude negative effects on *interest* compared to the effects of their regular interventions. One of these two results is nonetheless nonsignificant and is the result of a calculation involving little data (Table 1: teacher “Felix”). Nonetheless, only one teacher out of the six that are presented on Table 1 recorded a modest nonsignificant positive result. With respect to *self-concept* (Table 2), small or medium negative effects were recorded for all noticeable results, although only one was significant. Strangely, collaborative learning nonetheless recorded “small to medium” positive results for *preference* among three teachers. Only one teacher recorded negative results for this dimension.

Two teachers recoded changes that went in the same direction for more than one dimension (Marianne and Laurence both have two negative dimensions), but others obtained divergent results (Roseline obtained two positive dimensions and one negative dimension).

We point out that these last results were produced with the smallest groups of students, while the negative results were for the most part recorded in the large groups. So group size may have had some bearing on the success of this type of intervention. Regardless, overall, the rather negative results compel us to favour the hypothesis that collaborative learning, such as it was run in our teachers’ classes, did not produce the predicted positive effects, quite the contrary. Teacher comments during learning community activities had already allowed us to foresee this result. Teachers had formulated the hypothesis that the interdependence that is established among students during this type of intervention could have very negative effects on some of them (with respect to *self-concept*, to name just one), at least during students’ first experiences with this interdependence. Given the positive results obtained in earlier research studies (Akinbobola, 2009), which had recorded positive results but over long periods (4 months), we can formulate the hypothesis that the “collaborative” approach requires time before its interest becomes apparent; and that it is necessary for it to become more of an “operating culture” in the classroom than a simple “type of intervention” that is used from time to time. In our experiment, it is true that despite the relatively long duration of the interventions (5 to 10 teaching periods), these were "also" relatively short.

Project-Based Learning. Overall (Table 4), teachers having selected this type of intervention recorded increased *interest* from their students. This increase, significant and of medium effect, was also recorded in the students of the two teachers in Table 1, even though not-significant in one case. Strangely, *self-concept* recorded contradictory individual results. For two teachers, the "small" effect results were negative (and nonsignificant), for a third they were positive, significant and with an almost "large" effect (d=0.78). It thus seems as though teachers were not all able to cultivate *self-concept* the same way when developing their student projects. Finally, project-based learning also recorded contradictory results for *preference*, corresponding more or less with the scores for *self-concept*, and this, unsurprisingly, for the same teachers. We thus believe that these results support the hypothesis that the learning community was able, overall, to increase students' *interest* through "project-based" interventions, but also that this increase remains highly sensitive to the way in which these interventions are understood, designed and eventually led (run) in the classroom.

Conclusion

We believe that we have been able to show that it is possible, via a learning community initiative, inspired by the one used at the *Research Chair on youth's interest in science and technology* (CRIJEST) (i.e. made up of teachers, educational consultants and researchers, over six days) to produce generally positive results on students' interest for science and technology. These effects can be achieved via collective attempts to understand, design and implement interventions in the classroom based on scientific inquiry, context-based learning or project-based learning, such as these types of interventions have been defined and described in theory. We nonetheless observe that despite coordinated efforts, things can go very differently from teacher to teacher in reality, with results varying accordingly.

An important exception appears from the analysis of results obtained by teachers who tried to implement the collaborative approach. Indeed, generally negative effects were recorded with respect to the interventions developed by the teachers. It is thus possible that, for their positive effects to be seen, such approaches require much more time than what was allotted in our experiment, or, a second hypothesis, we can expect that they will simply produce negative effects on interest, in particular on *self-concept*. Indeed, it remains plausible that an increase in difficulty (and maybe also in the learning process) may in some cases be accompanied by decreases in interest. Curiously, and defying our attempts at an explanation, the score for *preference* can increase while scores for the other dimensions plummet.

Let us also point out that self-concept also recorded negative results for other types of interventions. Research studies in psychology show that in general, when variables of this type go down, it is often because the persons in whom they are measured have received negative feedback from authority figures (parents, teachers), or have the impression that they failed to meet their expectations. Might it be that the teachers involved in this research study in some cases indicated that their expectations were higher for the experimental groups than for the control groups?

At the conclusion of this research, we believe that a learning community is a model that can produce positive effects but also requires that the messages that it conveys are clear. Some of the negative effects that can result from the great freedom brought by open exchanges between peers and the sharing of theoretical and practical expertise are a certain dispersion and a loss of message clarity or a threat to the attainment of the objectives. The use of supervisory methods in instructional development is often encouraged, but the associated costs are significant (release of teachers, continued support on the part of educational consultants, etc.). In a future version of the *CRIJEST* learning community we may invite fewer teachers or prefer to work with a smaller number of intervention types, and perform a close follow-up of the methods used to implement the variables selected by the teachers.

In future studies, it would also be interesting to focus the use of the pre-/post-test questionnaire on the dimensions studied, and to avoid dividing the questionnaire into two sub-questionnaires, which would increase the number of available data for each question. Indeed, it is where we have the most data that the results are more solid and more frequently significant. We may also choose to use the "*preference*" variable, which seems less robust and more at the mercy of divergent influences (as all of them are related to local realities) by considering it discipline by discipline. Indeed, it is possible that preference for certain disciplines remains resistant (e.g.: for physical education), making it more difficult to measure variations. Nonetheless, we will use *interest for ST in school* and *self-concept* in the same way as in this study as these two dimensions seem in several cases to evolve independently, while both constituting elements of interest. Finally, in the future, it will be interesting to see directly what happens in the classrooms in order to compare the specific interventions with changes in interest.

In any case, we will hold working meetings to determine the best ways to achieve interventions that will produce results that are more often conclusive or significant. It is indeed cause for regret that several programmed interventions simply did not produce significant differences, or of noticeable effect. Ultimately, it is possible that these "enhanced" interventions simply do not produce any real differences, but the fact remains that it is also very plausible that they were simply "missed" opportunities. One possibility for securing experimental measures would have been to impose a ready-made planning on the teachers, but it seemed to us that the training would have provided the teachers with much less possibility for professional growth.

Finally, we believe that further quasi-experimental research in authentic school settings should be led in the field of education, in spite of the challenges this poses. Such research could contribute to shedding light on the dynamics of interest, as well as that of learning (and training), and their possible combinations. It could test other types of interventions, as well as some of their elements, or simply test the different ways to implement them. Finally, we would like to encourage research that involves teachers in a dynamic way. This research shows that not only do teachers have the opportunity to better understand the world of theory, but university professors are obliged to keep both feet on the ground, which ultimately allows them to have more credibility with teachers during results-sharing meetings. At

CRIJEST, the interface between theoretical expertise and practice has proven to be extremely fertile ground for ideas, dynamics and new projects.

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Corresponding Author Contact Information

Author name: Patrice Potvin

Département de didactique, Faculté des sciences de l'éducation

Université du Québec à Montréal, Canada

Email : potvin.patrice@uqam.ca

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