International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

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INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
http://dx.doi.org/10.1080/09500693.2016.1183267

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Enhancing literacy practices in science classrooms through a professional development program for Canadian minority-language teachers

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ABSTRACT

Literacy in the Science Classroom Project was a three-year professional development (PD) program supporting minority-language secondary teachers' use of effective language-based instructional strategies for teaching science. Our primary objective was to determine how teacher beliefs and practices changed over time and how these were enacted in different classrooms. We also wanted to identify the challenges and enablers to implementing these literacy strategies and practices at the classroom, school, and district levels. Data collection involved both qualitative and quantitative methodologies: student questionnaires; interviews with teachers, principals, and mentor; and focus groups with students. The findings suggest that the program had an impact on beliefs and practices commensurate with the workshop participation of individual teachers. These language-enhanced teacher practices also had a positive impact on the use of talking, reading and writing by students in the science classroom. Finally, continuing PD support may be needed in certain jurisdictions for strengthening minority-language programs given the high teacher mobility in content-area classrooms evident in this study.

ARTICLE HISTORY
Received 20 July 2015
Accepted 23 April 2016

KEYWORDS
Language skills; literacy; minority group teachers; professional development; science education

Canadian students have generally performed well in international assessments. In the last round of the Programme for International Student Assessment, or PISA (Organisation for Economic Co-Operation and Development [OECD], 2013), Canadian 15-year-olds performed above the average of 65 participating countries. Within the country, however, these reports often mask major differences between Canada's two official-language groups with students in majority-language schools typically outperforming students in minority-language schools (Brochu, Gluszynski, & Cartwright, 2011). A similar trend has been regularly observed in national assessments of reading and writing, as well as in mathematics and science, particularly on those test items involving problem-solving and language processing (Council of Ministers of Education, Canada [CMEC], 2008, 2010, 2011).

An analytical report prepared for the pan-Canadian French as a first language project suggested that 'a pedagogical approach specific to a minority setting could prove to be a

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long-term solution to problems of student performance in minority francophone schools in Canada' (CMEC, 2004, p. 33). The socio-demographic reality of living in a minority-language context may account for the weaker literacy skills and concomitant underperformance of Francophones in national and international assessments (Brochu et al., 2011; Rivard & Cormier, 2008; SPR Associates Inc., 2008). Brown (2011) argued that: 'pedagogy should be able to insure that all students [are] able to learn both the concept and language of science despite the socio-political nature of language' (p. 694). Rivard and Cormier (2008) described the challenges of teaching science in the minority Francophone context and recommended providing a rich array of linguistic and discursive opportunities in the classroom to compensate for the pervasiveness and attractiveness of English, the dominant language. The present study answers this call by examining the impact of a professional development (PD) program for supporting secondary science teachers in minority-language schools.

We review three areas of research that informed the design of the PD program, as well as the present study assessing its impact: the challenges of minority-language education in Canada, adolescent literacy instruction in science classrooms, and the PD literature.

Literature review

Minority-language education in Canada

There are many linguistic minorities in Canada, but only two groups have official language status and thus have the constitutional right to education in their mother tongue: Anglophones, or the English-speaking population, and Francophones or French speakers. Although approximately 20% of Canadians are Francophone, the population is not distributed uniformly across the country with the vast majority living in the province of Québec. The Francophone minority-language group constitutes less than 5% of the population in Manitoba, a province that is primarily English speaking like the rest of the country outside of Québec (Statistics Canada, 2012). Since 1994, the French-speaking minority in Manitoba has had the right to their own schools, as well as to a school board for managing them across the entire province. With the exception of English Language Arts, students in these schools complete all of their academic work in French, the minority language. Although the curricula in English schools and French schools are comparable within each of the provinces and territories, the minority-language schools are still confronted with many challenges (Gilbert, LeTouzé, Thériault, & Landry, 2004).

Minority Francophone schools and school boards are small in comparison to their English counterparts and thus do not benefit from the same economies of scale (Canadian Council on Learning, 2009). Locating appropriate French-language educational materials, recruiting qualified personnel, particularly in specialized areas like science, and finding suitable opportunities for PD are all problematic (CMEC, 2000, 2005). Teachers are also affected in that the workloads in these schools are generally heavier and more disparate and they typically encounter much greater expectations from the community (Gilbert et al., 2004). They often contend with multi-grade classes while working with very limited resources and support in small isolated English-dominant communities (CMEC, 2009). Moreover, many of these same respondents suggested that better opportunities for in-service training would ameliorate the situation.

For their part, Francophone students in minority settings generally have less favorable attitudes toward science than their Anglophone counterparts (CMEC, 2000, 2004; Pruneau & Langis, 2002). Many of these students also display signs of linguistic insecurity in school and other public spaces (Boudreau & Dubois, 1992). Most of their linguistic contacts outside of school are in English (CMEC, 2010; Martel & Villeneuve, 1995), and they more often begin school underprepared, particularly children of exogamous households in which only one parent speaks French (Gilbert et al., 2004). Moreover, almost two-thirds of students enrolled in Francophone schools are from exogamous families, which means that even the home environment is linguistically compromised for many in terms of optimal conditions for acquiring the minority language. Francophone students mostly identify themselves as bilingual, rather than as strict Francophones (Gérin-Lajoie, 2010). Less than half use the minority language most often while at home (CMEC, 2010). They are also less prone to using cognitive strategies while reading and demonstrate more avoidance behaviors when encountering comprehension difficulties (CMEC, 2004).

The CMEC (2010) recently examined differences in reading performance from the 2007 Pan-Canadian Assessment Program related to both language of instruction and minority/majority status. Although all students were assessed in the language of instruction of their school, English or French, the design allowed researchers to tease out its combined effect with linguistic status on reading behaviors. Statistically significant differences were observed in reading performance within the group of minority Francophone students based on the extent to which teachers reported using reading strategies in the classroom. For students in all language groups, reading for meaning and the use of reading routines in the classroom tended to be positively related to higher reading scores.

Moreover, the results of the 2009 PISA on reading suggest that 'students who are highly engaged in a wide range of reading activities and who adopt particular strategies to aid them in their learning are more likely than other students to be effective learners' (OECD, 2010a, p. 26). The report described this type of reading behavior as being 'wide and deep' (p. 16). Although Canadian 15-year-olds were among the top performers in terms of mean reading score, they were still below the OECD average for wide and deep reading habits. Furthermore, they were also below average in terms of awareness of effective strategies for understanding and remembering information. Although the data have not yet been disaggregated, we suspect that many minority Francophone Canadian students would be characterized as surface and narrow readers, lacking effective strategies for processing texts while reading a limited assortment of materials. We hypothesize that using a structured approach with these struggling minority-language readers, teaching them effective strategies for performing diverse literacy tasks while using a wide variety of interesting and authentic science texts to address the needs of all learners, would enhance their science learning.

Adolescent literacy instruction in science classrooms

Helping teachers develop effective instructional practices for working with text is important as national and international assessments of reading and writing suggest important weaknesses in students' abilities for comprehending informational texts, for reading critically, and for writing effectively (Grenier et al., 2008; National Center for Education Statistics, 2009; Salahu-Din, Persky, & Miller, 2008). Across all OECD countries participating in the 2009 Programme for International Student Assessment that is specifically based on reading informational texts and genres, 81.2% of 15-year-olds scored at or above proficiency level 2, which is the basic level required for productive participation in society (OECD, 2010b, p. 47). Nonetheless, the report concludes:

> The results of PISA 2009 show wide differences between countries in the knowledge and skills of 15-year-olds in *reading literacy*. […] The difference in reading performances *within* countries is generally even greater […]. Addressing the educational needs of such diverse populations and narrowing the observed gaps in student performance remains a formidable challenge for all countries. (OECD, 2010b, p. 157)

The CMEC (2008) had also underlined the need for improvement in student literacy:

> While students appear to understand what is expected of them in reading, […] there is room for improvement in the quality and clarity of their interpretation of and reflection on a text. As well, there are sufficient numbers of students at level 1 for whom reading of this nature is still an elusive activity. (p. 118)

Science classrooms have an enormous potential for developing language skills (Fang & Wei, 2010). Yet, science teachers devote little class time to the language of science, including the reading and writing of science texts (Osborne & Dillon, 2008; Rivard & Levesque, 2011). Science teachers generally lack practical knowledge for integrating language-based activities in their science teaching (Kiuhara, Graham, & Hawken, 2009; Love, 2010). Furthermore, most see their role as primarily teaching the content and processes specific to science despite evidence suggesting that science and language are intricately linked (Norris & Phillips, 2003; O'Brien, Stewart, & Moje, 1995; Yore & Treagust, 2006). Cromley (2009) observed that reading scores and science scores for students participating in the PISA were highly correlated and suggested that reading proficiency may actually enhance science achievement. O'Reilly and McNamara (2007) determined that reading skill and strategic reading knowledge reliably predicted various measures of science achievement in high school students. They concluded that 'reading skill helped the learner compensate for deficits in science knowledge for most measures of achievement' (p. 161). In our view, including a literacy component in the science classroom would be an effective approach for strengthening minority Francophone students' abilities to work with text and to learn science (Norris & Phillips, 2012; Wang, Chen, Fang, & Chou, 2014). Although disciplinary literacy is the ultimate aim of all secondary science education, we believe that foundational or generic literacy instruction is a crucial bridge for many linguistically struggling learners (Faggella-Luby, Graner, Deshler, & Drew, 2012; Lai, Wilson, McNaughton, & Hsiao, 2014; Moje, 2008; Shanahan & Shanahan, 2008).

Effective PD

In planning the program and designing the research study, we relied heavily on the PD literature about the characteristics of effective programs, generally, and about interventions with science teachers specifically, especially those dealing with the educational needs of linguistically diverse students (Borko, 2004; Garet, Porter, Desimone, Birman, & Yoon, 2001; Lee, Deaktor, Enders, & Lambert, 2008; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010; Penuel, Fishman, Yamaguchi, & Gallagher, 2007; Rogers et al., 2007; Wayne, Yoon, Zhu, Cronen, & Garet, 2008). Questions related to teacher knowledge and beliefs, curriculum, school and classroom culture, choice of facilitators, and resources were all addressed during the design phase (Loucks-Horsley et al., 2010). Desimone (2009) identified five features that can determine the effectiveness of a program: '(a) content focus, (b) active learning, (c) coherence, (d) duration, and (e) collective participation' (p. 183). In our program, we wanted to transform participating teachers' knowledge and beliefs about the role of talking, reading, and writing in content-area classrooms, as well as their practices while teaching secondary science. We considered these five critical features in designing the PD program. For instance, our program included 10 full-day sessions over a three-year period, as well as in-school support for the participating teachers between sessions. We believed that this would be sufficient for effecting the desired changes in participants and for ensuring that these practices were sustainable over time (Banilower, Heck, & Weiss, 2007; Supovitz & Turner, 2000). The alignment of the PD program with the other features has been described in an earlier article (Rivard & Gueye, 2015).

We also consulted two literature reviews that examined issues related to content-area instruction for English language learners (ELLs) (Janzen, 2008; Lee, 2005). Janzen reviewed the literature for history, mathematics, English Language Arts, and Science, whereas Lee focused specifically on science education. Both of these authors concluded that teachers generally are poorly prepared for working with linguistically struggling learners and that additional research on both their initial preparation and PD merits attention. Furthermore, they concluded that teachers need considerable time to appropriate the skills required for effectively supporting these struggling learners and that there is a paucity of studies at the secondary level. Finally, Janzen concluded that the explicit instruction of literacy strategies was absent in the research studies reviewed. In terms of language ecology, these studies can be characterized as focusing on how best to integrate ELLs into mainstream English-Language elementary classrooms.

Our challenge here was very different and involved how best to teach minority-language French-speaking secondary students despite the overwhelming presence of the dominant English language, the *lingua franca* which pervades the cultural and institutional fabric of Canada outside of Québec. Further, our PD program addressed issues related to the explicit instruction of literacy strategies in the science classroom. This paper reports the findings from a small-scale inquiry in which we attempted to correlate workshop participation with changes in both beliefs and practices despite the typical addition or attrition of participants over time.

Purpose of the study

The primary objective of our research study was to determine how minority Francophone teacher beliefs and practices changed as a result of a small-scale PD program on language-enhanced science instruction and the impact of these changes on learners. We also wanted to identify the challenges and enablers to implementing these literacy strategies and practices at the classroom, school, and district levels.

Context and participants

The PD program

Literacy in the Science Classroom Project was a three-year PD program for supporting secondary science teachers in minority-language schools. Since 2008, we have been working with minority-language grade nine science teachers from a province-wide francophone school district in a PD program meant to enhance instructional practices for reading and writing texts in the science classroom.

We built our program on findings from authoritative sources in the field: the *National Reading Panel* (National Institute of Child Health and Human Development, 2000) and the reports *Reading next – a vision for action and research in middle and high school literacy* (Biancarosa & Snow, 2006) and *Writing next: Effective strategies to improve writing of adolescents in middle and high school* (Graham & Perin, 2007), as well as on findings from the extant research literatures in both literacy and science education. Our review identified strategies and practices that seemed most promising for enhancing classroom instruction and learning. On the basis of these studies and the research literature on minority-language education, Rivard, Cormier, and Turnbull (2012) identified six research-based instructional practices for enhancing reading comprehension in science classrooms including: (a) metacognitive conversations, (b) collaboration and discussion, (c) identifying text structure, (d) using authentic text, (e) strategies for learning vocabulary, and the (f) explicit teaching of comprehension strategies. In a comparable review of the literature on writing in science, Rivard (2009) recommended that minority-language science students would benefit from a greater use of varied discursive tasks, such as summarizing, as well as from the explicit teaching of those text types which are commonplace in science writing, specifically descriptive, explanatory, and argumentative.

Four full-day in-service workshops were offered in the first year of the program during 2008–2009, one of which was a make-up session to accommodate newly recruited participants. Although the primary focus of these early sessions was on strategies and practices for reading texts in the science classroom, we also addressed the role of peer talk and collaboration for supporting learning. In the 2009–2010 school year, three more full-day sessions were held. The initial workshop during the fall term focused predominantly on reading in science, while in later sessions during the spring, we began to examine the use of writing in the science classroom. During the second year of the program, we also recruited a retired education professor to act as mentor or literacy coach for participants in the program (Appleton, 2008; Bradbury, 2010; Feiman-Nemser, 2001). The mentor planned lessons with them, modeled strategies, observed lessons, and gave them feedback while also mentoring them about literacy instruction. As Feiman-Nemser (2001) suggests: mentors provide an invaluable service by 'reinforcing theoretical ideas in context' (p. 24). We continued to focus on reading and writing in science during the 2010–2011 school year: two days in both the fall and the spring terms. A brief overview of the session activities and content is included in Table 1. However, a fuller description of these workshops is available elsewhere (Lentz & Dubois-Jacques, 2011/2012; Rivard & Gueye, 2015).

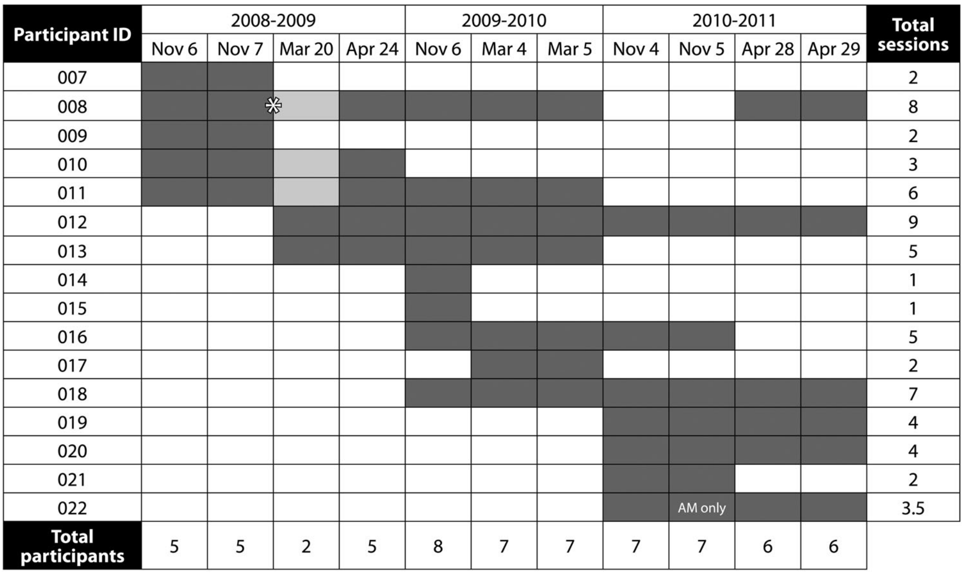
Participants

All of the teachers who taught grade nine Science in the Francophone school district were invited to participate in this PD program in the fall of 2008. Eleven of the possible 15 schools in the province, which spans an area larger than France, accepted our

Table 1. Brief overview of the PD sessions.

Session	Days (*n*)	Activities and content
2008–2009		
Fall	2	• Initial perceptions about the nature of reading • Selected approaches for reading in science: pre-reading, reading, and post-reading • A toolkit of reading strategies
Spring	1	• Modeling the use of reading strategies using the textbook and authentic texts • Designing a reading intervention for classroom instruction using web-based texts • Using talk and collaboration to support science learning
2009–2010		
Fall	1	• Representing texts graphically • Strategies for effectively integrating language and science • Levels of reading comprehension • Resources for content-area reading in science
Spring	2	• Initial perceptions about the nature of writing • Selected approaches for writing in science • Assessing the effectiveness of written texts • Using graphic organizers as templates for writing • Writing descriptions and explanations • Resources for content-area writing in science
2010–2011		
Fall	2	• Analysis of genre and text structure • The writing process: strategies for drafting and revising texts • Summary, journal, and argumentative writing • Selected approaches for argumentative writing • Designing effective classroom writing assignments
Spring	2	• Sharing classroom practices for reading and writing • Analysis of lab reports provided by participants • Strategies for enhancing the writing of lab reports • Role of content literacy in minority-language education • Language in science: synthesis and conclusions

invitation. In all of these schools, a single teacher taught the grade nine Science program. Over the three-year span of the project, 16 teachers participated at one time or another in the PD program. Participation in the 10 sessions ranged from one to nine sessions with teachers dropping out when reassigned to other schools and subject areas (four teachers) or while on sick leave or compassionate leave (two teachers), or joining the group midstream as new recruits to our program (seven teachers) or as new teachers in the district or to science teaching (four teachers). Newly recruited participants to the program were all given a personal briefing to facilitate their integration into the group. Participation of individual teachers over the course of the three-year PD program is shown in Figure 1. The teachers were mostly male and mainly had a BA or other general studies degree. Few were specialized in science. Although slightly more than two-thirds of participants had taught in schools for more than five years, less than one-third of them had been teaching science for this same period. The schools were mainly rural and largely organized in a K–12 configuration. The class size was relatively small with a mean of 16.5 students, though 40% of the teachers had the additional challenge of teaching multi-grade science classes.



* The dark gray represents the sessions that individual participants attended. The lighter gray is used to show the continued participation of three teachers already in the program. The March 20th workshop was a make-up session in which two newly recruited teachers participated.

Figure 1. Workshop participation of individual teachers during the PD program.

Data collection and analysis[1]

Mixed methods were used including both qualitative and quantitative approaches for data collection and analysis (Creswell, 2009). We involved various stakeholders, including students, teachers, the mentor, school and district administrators in order to triangulate the results. Despite this being a small-scale study, we wished to discern trends and determine the impact of the PD program by including multiple viewpoints.

Student questionnaire

Students were surveyed about the use of language-based strategies in their science classrooms. For this purpose, we developed a questionnaire (QE7) for use in the first year of the program that included 23 open-ended questions. This pilot instrument was used in five different schools with 75 students in total. On the basis of student responses to these questions, we revised the pilot instrument. The revised questionnaire (QE13) included 25 questions in total: 17 closed-ended questions, four open-ended questions and four others which included an initial closed question followed by an open question. This instrument was used in year two of the program with 132 students representing all of the participating schools and again in year three with 95 students across seven of the eight possible schools. As such, all but one of the schools were represented in the

[1]All of the instruments were developed in French and later translated to English for the purpose of this paper. Participants' comments have also been translated into English. The following transcription codes are used throughout: square brackets indicate deletion or addition of text to facilitate comprehension of the transcript; '/': indicates a pause of less than two seconds; '//': indicates a pause of greater than two seconds.

dataset for years two and three. As the pilot instrument consisted of mainly open-ended questions, these were not analyzed any further. The data collected from the student questionnaires in the second and final years of the program were analyzed to determine student perceptions regarding classroom practices. Questions explored student beliefs and understandings regarding the use of talking, reading, and writing in the classroom, as well as their use of particular strategies, such as note-taking and summary writing, for learning science. Our objective with the analysis was to determine if student perceptions changed as a result of their teachers' evolving beliefs and practices during the PD program.

Interviews and focus groups

We interviewed eight participants during the second year of the project using a semi-structured interview protocol which focused on the use of reading and writing while teaching science, as well as on factors which enhanced or hindered the use of these language-based practices in the classroom. A summary translation of the French questions included in the teacher interview protocol can be found in the Appendix. In the final year of the project, we interviewed all seven teachers still in the program, as well as two other teachers who had left the program. Overall, we interviewed 12 different teachers out of a possible 16. The four teachers who were not interviewed either had been reassigned to other subjects or schools and were therefore unavailable during the interview period. The transcripts of the teacher interviews were read by two members of the research team. Teacher responses were initially analyzed for patterns with respect to changes in their beliefs and practices, as well as to factors inhibiting or promoting change. Emerging themes were identified, compared, and possible assignment to categories discussed (Corbin & Strauss, 2008). Two other members of the research team reviewed this tentative list of themes prior to independently reading through all of the transcripts. This validation process yielded two additional themes, specifically with respect to the impact of the program on students. This first phase of the data analysis produced 16 themes subsumed under four categories that are summarized in Table 2.

Table 2. Inductively developed thematic categories.

Code	Thematic category	Definition
B1	Teacher beliefs	Teachers are aware of the importance of language while teaching science and for supporting learners
B2	Teacher beliefs	Teachers believe that peer talk and collaboration can support learning
B3	Teacher beliefs	Teachers recognize that classroom practice must meet the challenges of teaching in FL1
P1	Teacher practices	Teachers have a bigger toolbox of effective strategies
P2	Teacher practices	Teachers support students in reading and writing
P3	Teacher practices	Teachers use authentic texts more often
P4	Teacher practices	Teachers work primarily with expository texts to inform students
P5	Teacher practices	Teachers are more sensitive to the needs of diverse learners
P6	Teacher practices	Teachers intend on sustaining these practices
P7	Teacher practices	Teachers have transferred these practices to other grade levels and subjects
S1	Impact on students	Students seem more engaged
S2	Impact on students	Teachers report an improvement in students' reading and writing abilities
S3	Impact on students	Students seem to enjoy the literacy activities
F1	+/− factors on PD	Heavy course loads, time constraints, and lack of resources (−)
F2	+/− factors on PD	Discussing, collaborating and sharing experiences with colleagues (+)
F3	+/− factors on PD	Mentoring was important in adapting ideas to classroom practice (+)

Transcripts of the teacher interviews were coded for evidence of literacy beliefs and practices, impact on students, as well as factors promoting or inhibiting implementation. Each interview was independently coded by two research assistants who met afterwards to compare their coding and resolve any differences through consensus. Inter-rater reliability averaged 84% agreement for the thematic coding of interviews. Once they had completed all of the interviews, they evaluated the degree of implementation or the intensity of the respondent's beliefs as manifested in their comments using a three-point rating scale: no evidence of congruence in transcript (0); partially, or some evidence of congruence (1); and strongly congruent (2). For instance, one of the themes under the teacher beliefs category included recognizing that classroom practice must meet the challenges of teaching in FL1, the Francophone minority setting. Teacher 16 was rated a two for this category on the basis of the following assertion which was judged to be strongly congruent:

> The fact that we are in a minority setting gives us another opportunity and another reason to read in science, to write in science, to enrich the science vocabulary of students so that they appropriate science in French. […] It gives them another reason to do everything in French. Because science, it is really // is very present in their daily lives. So, if now, they can do that in French, that is wonderful [June, 2011].

Another teacher, T013, was given a one for evidence of partial congruence in the transcript:

> Well, I have to say that I hadn't thought about that before, / that it would be so different. I know that it is challenging because we live in a minority context, but it had never occurred to me that it would be such a problem. The students don't read science in French. I had never thought of that. So [the PD program] opened my eyes to this [reality]. The program really helped me that way [June, 2010].

Finally, T017 was assigned a zero because no evidence of congruence was found in the transcript with regard to the challenges of teaching in a minority context:

> I don't think that it is really // We are a minority in terms of the number of Francophones, but we are in a Francophone school, so most of our students are nevertheless fairly capable. So / I don't think that being a minority group has much of an impact [June, 2010].

Inter-rater agreement was 86% for scoring the degree of implementation of all of the themes in the interview transcripts. Scores for each of the 16 themes were obtained and subtotals were calculated for each of the four categories: teacher beliefs (across 3 themes), teacher practices (7 themes), impact on students (3 themes), and factors inhibiting or promoting the PD program (3 themes). As such, the maximum possible score across the four categories was 32 points with overall ratings for the eleven teachers ranging from 5 to 28 points. Pearson product-moment correlation coefficients were calculated using the category scores for each teacher to determine the relationship between workshop participation with each of these four categories, as well as among them.

Furthermore, we interviewed a number of school principals, the mentor, and also organized student focus groups in several schools. However, these were not scored, but were used to provide views from other perspectives for triangulating our findings.

Results and discussion

Student questionnaire

Significant differences were observed for a question asking students about instructional practices, specifically about whether or not they had been taught how to write different types of texts in science class, $X^2 = 4.094$, $p = .043$. We used the Pearson Chi-squared test of independence to determine whether or not students who had been taught to write different types of texts responded differently to selected questions exploring the impact of the PD program on various literacy practices. This cross tabulation analysis is provided in Table 3. We believed that this might allow us to mitigate the effect of the differential participation of teachers during the PD program. A greater proportion of students who had been taught how to write texts indicated that they wrote summaries more often (61.2% versus 43.6% with $p = .009$). Similarly, these students also tended to write explanations of lab observations (75.2% vs. 54.7% with $p = .001$) and to write lab reports (61.0% vs. 38.0% with $p < .001$) more often. Furthermore, these same students tended to more often work from a plan (61.2% vs. 45.3% with $p = .019$), use questions to guide their research (48.0% vs. 29.1% with $p = .004$), as well as to guide their writing (33.0% vs. 15.0% with $p = .002$).

Interviews and focus groups

Salient findings from the interviews with teachers, principals, and mentor, as well as from the student focus groups and community forum, are presented below under the four thematic categories described earlier.

Beliefs about literacy

The teachers unanimously underlined the difficulties that their students encountered with reading and writing. Several mentioned that they believed that all teachers had an

Table 3. Cross tabulation analysis comparing 'being taught how to write texts' with selected items from the student questionnaire.

Questionnaire Item	Taught how to write (%) Yes ($n = 105$)	Taught how to write (%) No ($n = 118$)	χ^2	P
Learning science is also writing about science	83.8	73.7	3.343	.068
In science class, I write to answer questions for homework and on tests	81.9	81.5	.006	.940
In science class, I write to note what I have to remember	80.0	73.1	1.466	.226
In science class, I write to understand what I have to learn	51.4	58.8	1.234	.267
In science class, I write to prepare assignments and projects	67.6	56.3	3.020	.082
In science class, I write to develop my ideas	39.0	30.3	1.913	.167
In science class, I write in a journal	38.5	26.3	3.776	.052
In science class, I write summaries	61.2	43.6	6.777	.009**
In science class, I write explanations for observations in the lab	75.2	54.7	10.182	.001**
In science class, I write texts expressing my opinions	34.6	24.8	2.562	.109
In science class, I write lab reports	61.0	38.0	15.254	<.001**
In science class, I write other types of texts	34.3	35.3	.025	.874
When I write a text in science class, I work from a plan	61.2	45.3	5.532	.019*
When I write a text in science class, I first research the topic	58.3	51.3	1.058	.304
When I write a text in science class, I formulate a question to guide my research	48.0	29.1	8.227	.004**
When I write a text in science class, I have a goal in mind	48.0	41.4	.953	.329
When I write a text in science class, I use questions to guide me	33.0	15.0	9.522	.002**
In science class, do you discuss ideas with peers before writing?	79.0	68.6	3.091	.079

*Chi-square test or Fisher's exact test is significant at the .05 level.
**Chi-square test or Fisher's exact test is significant at the .01 level.

obligation to develop the literacy skills of students, not just those teaching Language Arts. Others indicated that it was important to give students tools for learning rather than 'just teaching science because most of them will not continue in science after secondary school'. Many of the teachers observed that their students spoke French only in the classroom, so they viewed their role in scaffolding language acquisition in a content area like science to be of paramount importance. One teacher suggested that his professional identity had been transformed by participating in the program.

> It's mainly my identity as teacher in a minority French school that has been enriched by this experience. Classroom strategies for teaching these students are not obvious when you consider that many of them only speak English at home and have learned French almost as a second language. As teachers, we tend to think that these students are capable of reading and understanding any text. But that is not always the case. (T018, 2009-10-11)

For many of the teachers, the science classroom became a privileged space for using French, thereby enabling these minority students to further enhance their language competencies. The school principals and consultants also corroborated teachers' view that all teachers share responsibility for developing student literacy, particularly in a minority-language setting. Many of the teachers also identified the critical role of talk and collaboration for clarifying and remembering ideas, for task engagement, and for co-constructing knowledge. One teacher explained why student talk was so important.

> Yes. Again, it is more clear in my mind that yes, it is an expectation. Did I use group work in that particular class? Did I give students opportunities to talk about their ideas, to share written texts, or to create a text together? Because the process involves discussing and negotiating word choices and expressions. So, I observed them do that and now I try to include it in almost every class. (T016, 2011-06-01)

Some of the students also mentioned the importance of talk and collaboration for learning science.

Literacy practices

Teachers reported using pre-reading strategies more often for teaching essential vocabulary and for establishing goals for specific literacy tasks. They also identified literacy tasks that they found to be especially useful in the science classroom: writing summaries and Role, Audience, Format, and Topic (RAFT) assignments, concept mapping as a planning tool for writing, and Jigsaw for organizing collaborative learning. One teacher indicated that the use of these practices tended to make students less dependent on authority for their learning. One beginning teacher stated that the PD program had prepared him for classroom teaching better than his initial teacher education program. Many of the teachers reported using a variety of strategies for scaffolding text comprehension and text production by students. The teachers reported that they now used authentic texts, such as science magazines and web-based articles, more often, but that they still considered the textbook as an important source of science content. One of the teachers suggested that using authentic texts allowed her to develop critical reading skills in students.

> In my view, there are strategies that are more relevant when reading an authentic text. For example: identifying the authors, their use of language, their style of writing. It's a much richer discussion when the text is taken from the newspaper or magazine. In the textbook,

> it's a lot of description. We can't really talk about the author's stance, opinions, or the choice of vocabulary or style. (T016, 2011-06-01)

Identifying the author's stance, purpose, and intended audience are all important rhetorical functions that teachers should develop in adolescent readers for analyzing discourse. Nonetheless, teachers also indicated that evaluating the readability of these supplementary texts was a time-consuming but essential task. Moreover, the use of these in the classroom often demanded motivating and guiding students by using diverse reading strategies. Students in one of the focus groups suggested that many of these texts were more 'age-appropriate and interesting than the textbook'. Several teachers reported using argumentative texts on topics like global warming or embryonic stem cell research to explore Science, Technology, Society, and Environment links with students. Although one teacher mentioned that he would have needed additional time to 'really master the proposed strategies', most reported that they planned on continuing the use of these literacy practices after completion of the PD program. Many of the teachers also reported using these practices in other secondary science courses that they taught, such as biology, chemistry, and physics, as well as other content areas, such as social studies and mathematics. One teacher stated that the 'strategies were generic and could be used in all subjects'. Teachers also suggested that using these literacy practices allowed them to differentiate instruction to accommodate all students.

> I would say that it was one of the most useful inservice programs that I have ever attended […]. We learned so many practical things that can be used in the classroom. Not something that can only be used in an ideal situation. The strategies were useful with all students, regardless of their level, both weaker and stronger students. (T008, 2011-06-03)

Students in the focus groups also indicated that the 'strategies could be used anywhere' and that they should be 'used often to really benefit from them'. Several principals reported that the PD program even had an impact on the literacy practices of other teachers in their schools.

Impact on students

Teachers reported that students were more interested and more engaged with learning tasks. In the focus groups, students reported using many strategies prior, during, and after reading texts. For instance, one student identified a whole series of pre-reading strategies that the teacher had taught them to use for text comprehension.

> One strategy that our teacher taught us included scanning the title [and subtitles] prior to reading a text to first get a general impression of it, then looking at the figures [and drawings], and finally reading the first sentence in each paragraph before actually reading the text in depth. (S2, 2011-05-25)

One teacher suggested that 'student motivation was enhanced because the language activities were well structured' and they were more confident as a result. A student in one of the focus groups reported that:

> Our teacher would assign us to small groups for project work. Each group would have a different topic to research. We were asked to prepare summaries of the information that we read, then share these with the other groups. I found that we had a lot more ideas as a group, which was helpful. (S1, 2011-05-24)

This jigsaw activity integrated talk, reading, and writing in a collaborative environment. Another student in the same focus group suggested that processing formal science texts and translating them into more familiar everyday language helped them to learn the science content.

> Yes, we found lots of fairly readable texts on the Internet or in books. We had to prepare notes on these and share them with the entire class. *Comme cela on peut apprendre le sujet mais dans la langue plutôt adolescente, je dirais*. [This was useful because we could learn the content using adolescent language, I would say]. (S1, 2011-05-24)

Comments from students in the other focus groups corroborated these observations. Many of the students emphasized the importance of talk and collaboration for making sense of science texts and appropriating the language of science. The teachers indicated that the reading and writing of their students had improved, particularly those students who previously struggled with language-based activities. Students mentioned summarizing and using concept maps or other graphic organizers as strategies that were not only useful in processing text while reading, but also as templates for writing afterwards. Students also underlined the importance of both going beyond the text while including their opinions about science issues and collaborating with peers.

> Asking us to include what we thought, or our opinion about something, really made us think about the issue. You remember more that way instead of just reading. Reading and writing help a lot, but I find it even more helpful when we discuss in groups. (S3, 2011-05-24)

Factors promoting or inhibiting implementation

Teachers indicated that heavy course loads, little time for preparation, and lack of suitable resources were all major obstacles to implementing the literacy strategies. For instance, one teacher suggested that the mandated curriculum was fragmented and too broad in scope and that he felt obligated to 'teach to each objective in a sequential manner'. Several teachers mentioned that they felt isolated and would benefit from networking more often with their colleagues, either face-to-face or virtually. Interviews with the principals and the mentor corroborated the teachers' perceptions of major obstacles. Teachers were unanimous in their appreciation of being able to meet their colleagues, share their experiences, and discuss instructional practices freely without fear of retribution. One teacher reported that he had appreciated being able to observe the modelling of strategies during the workshop.

> I really appreciated the program, particularly the discussions with colleagues from all over the province. I also thought that the modelling [of strategies] was most helpful. It really showed me what I could take and transfer to my own classroom. (T19, 2011-06-06)

Others indicated that the sharing of ideas and resources had been particularly enriching. Teachers were enthusiastic in their praise of the mentor for facilitating the appropriation of literacy practices.

> In any case, it allowed me to sit down with her [the mentor], to discuss a particular strategy, and to adapt it to my situation. After the lesson, she would give me feedback on that. So, I found that very useful, very practical. Being able to ask questions of a resource person like that is important. (T16, 2009-10-07)

The mentor was the glue that kept participants engaged between the workshops which were generally separated by six-month intervals. The mentor, acting as literacy coach, would also facilitate the integration of new participants midstream during the program by working with them on an individual basis. One teacher suggested that she felt a 'certain moral pressure to try things [literacy activities] because she knew that the mentor would return to her classroom'. The principals also underlined the important contribution of the mentor in scaffolding their teachers' PD, not only those who participated in the PD program, but also others on staff who were touched by either the participant's enthusiasm or the mentor's direct support.

Analysis of teacher interviews

Transcripts of the teacher interviews were coded for evidence of literacy beliefs and practices, impact on students, as well as factors promoting or inhibiting implementation. Figure 2 summarizes the results of a correlation analysis. The data suggest that greater participation in the PD program is correlated with higher overall scores for beliefs about literacy ($r = .670$, $p = .024$) and for literacy practices ($r = .694$, $p = .018$). Overall scores for beliefs about literacy are also correlated with literacy practices ($r = .762$, $p = .006$).

	Literacy Practices	Impact on Students	Factors Promoting or Inhibiting	Beliefs about Literacy	Sessions
Literacy Practices					
Impact on Students	.755** $p = .007$				
Factors Promoting or Inhibiting	.589 $p = .057$	.203 $p = .549$			
Beliefs about Literacy	.762** $p = .006$	.430 $p = .186$	.316 $p = .343$		
Sessions	.694* $p = .018$	.428 $p = .189$	.051 $p = .881$	.670* $p = .024$	

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Figure 2. Pearson correlation matrix based on teacher interviews ($n = 11$) and workshop participation by sessions attended.

Moreover, these literacy practices are highly correlated with an impact on students in the science classroom ($r = .755$, $p = .007$). As predicted, 'factors promoting or inhibiting implementation' was the only thematic category for which no correlation was found. Many of these factors appear to be ubiquitous and were observed in the interview transcripts regardless of the extent of teacher participation in the program.

The pivotal role of the mentor

The mentor's role in enhancing the impact of our PD program was mentioned by almost all of the participating teachers, school principals, and school district consultants. The mentor worked closely with teachers while observing classroom instruction, modeling strategy use, collaboratively planning lessons, engaging in pre- and post-conference discussions on the integration of language with science. She also collected instructional materials which teachers developed and written texts produced by students. During the school year, the mentor made an average of 15.6 interventions with every participating teacher, tailoring her approach to specifically address their personal objectives while being guided by an action plan which they had developed together. Moreover, she documented each meeting with detailed notes and submitted these, along with instructional materials and student texts to the research team. As such, the mentor was in a privileged position for corroborating our research findings. After reviewing all of the field notes and classroom artifacts collected during the mentor's interventions, we interviewed her about the impact of the program.

When asked whether or not she had observed any changes in teacher beliefs over the course of the PD program, the mentor indicated that she had noted an initial awareness of the importance of literacy in participants followed by a need to acquire the requisite instructional tools.

> For the vast majority of teachers who participated in the program, I would say that it was initially developing an awareness for which I am ultimately responsible. After this initial recognition, they wanted to acquire the tools to support their students in becoming better readers and writers, so that they might succeed in science through reading and writing. (Mentor, 2012-06-26)

When asked about whether or not she had observed any changes in teaching practices, the mentor indicated that peer-group work was now better grounded in the principles of effective questioning, collaborative learning, and differentiated instruction. She remarked that teachers' questioning techniques had evolved from 'inquiring for the right answer to enabling students to reflect on their learning'. She indicated that teachers were more strategic in their use of peer-group discussion, sometimes using dyads in homogeneous groupings for ability, other times larger heterogeneous groupings, depending on the task, context, and instructional sequence. She observed that teachers more often differentiated their instruction to accommodate the diverse needs of their students. The mentor suggested that the teachers, particularly those with multi-grade classes, viewed literacy practices as a way of differentiating instruction through the selection of strategies, tasks, and texts.

We also asked the mentor about changes observed in the students, as well as about factors which may have promoted or hindered the PD efforts. Her views here again confirm our conclusions based on the teacher interviews; however, these will be detailed in a future paper which is in preparation on the role of mentoring in supporting small-scale PD programs.

We also asked the mentor to identify the teachers who had made the most progress during the program in integrating language with their science instruction. Two of the three teachers she identified were among the top three in terms of overall scores generated from the analysis of interviews. One of these teachers had set herself a goal of using differentiated instruction and authentic writing tasks more often. For example, she had her students read internet-based authentic texts on human fetal development from initial conception to birth in order to collaboratively produce an illustrated expository text on the subject that would be appropriate for younger readers in upper elementary. The other teacher had focused on acquiring a repertoire of strategies for teaching vocabulary and for managing peer-group work. The mentor indicated that this teacher was now a leader working with other teachers in his school and the school district in PD workshops on literacy. In short, all six teachers which the mentor identified as 'strong implementers' also, without exception, received the highest overall scores in our analysis of participant interviews. Conversely, the mentor was able to correctly identify the two participants who had obtained the lowest overall scores in this analysis. As such, the mentor's analysis provides strong corroborating evidence for our findings regarding changes in teacher beliefs and practices.

Conclusions

Although all small-*N* studies have inherent limits and should be interpreted cautiously, our research design provided multiple perspectives for assessing the impact of the PD program over its duration. We would argue that the findings of this study are not manifest in the individual data strands, but rather are embedded in the final tapestry that these weave together. Our research study shows how minority Francophone secondary teachers' beliefs and practices changed as a result of a small-scale PD program on language-enhanced science instruction and the impact of these changes on learners. As such, our findings may be useful to smaller jurisdictions wishing to provide PD for content-area teachers working with minority-language or second-language learners, particularly those at the middle school and secondary levels where there is currently a paucity of research (August & Shanahan, 2006; Janzen, 2008; Lee, 2005).

The student questionnaires provided us with quick snapshots of practices at various points in time, whereas the interview and focus group data provided views of both beliefs and practices which spanned greater lapses of time. Lee and Krajcik (2012) have argued that the vagaries of participant mobility, which can mitigate the impact of PD, are all too commonplace in educational research. Nonetheless, our findings suggest that the program clearly did have an impact on reading and writing, as well as on the effective use of talk and collaboration, in participants' classroom. The interview and focus group data provided valuable insight into participants' beliefs and views regarding the use of various strategies and practices for knowledge construction. Participating teachers developed an appreciation of their dual role as science and language teacher while students clearly explained how these practices were manifested in the science classroom. As such, the professional identities of teachers and the identities of learners changed over the course of the program. Moreover, our use of correlation analysis was an attempt to control for the effect of participant mobility in evaluating the impact of the PD program. The findings from the teacher interviews show a statistically significant correlation between workshop participation and teacher beliefs and practices, and that these literacy practices had an impact on students. This corroborates the findings of Banilower et al. (2007) study which showed that program impacts are discernible even before reaching the 80-hour threshold suggested by Supovitz and Turner (2000). The findings from the interviews with principals, consultants, and the mentor, as well as the student focus groups, all seem to corroborate this conclusion about program effectiveness. Nevertheless, more time may have been required to ensure that teachers felt comfortable with the various strategies, particularly those for framing writing assignments in the classroom. Extending the program to five years might have been required for meeting all of the literacy objectives of our PD program. One might even argue that continuous support should be provided to secondary content-area teachers in minority-language school districts to better accommodate the perpetual changes in staffing. Our findings also suggest that a mentor or literacy coach could perhaps provide the required support for helping these teachers integrate language with content teaching.

The PD program encouraged participants to share experiences with colleagues and to reflect often about their beliefs and practices during group discussions in the workshops, as well as individually with the mentor. Capps and Crawford (2013) argued that knowledge alone is insufficient, whereas active reflection 'can help to solidify new knowledge and assist in anchoring this knowledge in one's teaching practice' (p. 1971). We believe that this was a strength of the program, in that we created spaces for reflecting on the use of literacy practices in the science classroom. Since both the workshop facilitators and the mentor were not school based or even affiliated with the school district, teachers felt comfortable in sharing their concerns and taking risks in the classroom without fear of being evaluated (Hobson & McIntyre, 2013). Moreover, the collegial nature of these workshops encouraged participants to reflect upon the myriad ways in which these literacy practices could be enacted in their classroom for sense-making and co-constructing knowledge rather than for the simple rehearsal of knowledge (Adams & Pegg, 2012).

Furthermore, we believe that these findings may also be relevant to those teachers working with minority-language learners from other 'culturally and linguistically diverse' communities in which the goal is integration into mainstream classrooms (Lee et al., 2008). Helping these children acquire the literacy skills required to successfully integrate later into mainstream classrooms and to thrive academically is a formidable challenge for all educators (Lee & Buxton, 2013). However, support is essential if our goal is to ensure their smooth transition to the workplace and society as productive members (August & Shanahan, 2006; Wilson, 2013).

Ellis (2005) reports that there may still be as many as 6000 languages across the planet. Many countries already provide dedicated programs for minority-language children while others offer bilingual, immersion, or other second-language programs to support language acquisition. The findings of this study are particularly relevant to international science educators working in minority-language situations in which the dominant language has greater status, power, and prestige. Rivard and Levesque (2011) have written that 'minority Francophone students in Canada live in two parallel language worlds: one dominant, public, and prestigious; the other suppressed, private, and familiar' (p. 37). Similar situations exist in countries, such as Wales, the Philippines, New Zealand, and India, as well as many others across the globe where mother-tongue education is not only permitted, but also encouraged, to ensure linguistic and cultural survival. The challenge for teachers in these schools is how best to support the language development of students in the sheltered linguistic confines of the school and classroom, despite the overwhelming presence of a more dominant or higher status language. Although in many of these programs older students eventually transition to mainstream programs offered in the dominant language, this is not always the case, as with students in Canada and Wales currently studying secondary science in French and Welsh, respectively. Providing secondary science instruction in a minority language to students who are overwhelmingly immersed in an Anglophone world demands that teachers be particularly attentive to issues of language acquisition. Duff and Li (2009) argued that there is a 'close connection between identity and language learning, especially for minority groups, and [that we frequently observe] non-linear linguistic trajectories of language/literacy learning for many learners as they learn, forget, shift to other languages, and perhaps shift back again' (p. 6). Suitable spaces for negotiating and constructing strong social and linguistic identities must be provided throughout the cycle from childhood to adulthood in bilingual and multilingual societies. Minority-language students will make many border crossings across the linguistic divide as they move from home, to school, and to the workplace. Many will eventually acquire the linguistic capital required to be fully bilingual or plurilingual. However, others may choose to neglect their mother tongue and assimilate into mainstream society. Nonetheless, minority-language schools have a crucial role to play in diminishing the chances of assimilation and ensuring optimal conditions for linguistic growth during this trajectory.

Although most students in minority-language programs may be successful in acquiring basic literacy during the earlier years, many can flounder when confronted in middle and secondary school, or later at university, with increasingly complex literacy demands (August & Shanahan, 2006; Lee, Quinn, & Valdés, 2013; Schleppegrell & O'Hallaron, 2011; Shanahan & Shanahan, 2008). Our PD program attempted to support secondary science teachers' development of practices for scaffolding minority-language learners toward their acquisition of disciplinary literacy, while our small-scale study attempted to document its impact despite the confounding effect of teacher mobility. The findings suggest that the program had an impact on literacy beliefs and practices commensurate with the workshop participation of individual teachers. These language-enhanced teacher practices also had a positive impact on the use of talking, reading and writing by students in the science classroom. Finally, continuing PD support may be needed in certain jurisdictions for strengthening minority-language programs given the high teacher mobility in content-area classrooms evident in this study.

Funding information

This work was supported by the Social Sciences and Humanities Research Council of Canada under [grant number 833-2007-1008].

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Appendix: Summary Translation of the Teacher Interview Questions

1. How would you rate this in-service program on language and science? Give specific examples to illustrate your views.
2. How important is the teaching of reading and writing in minority francophone science classrooms?
3. Has the in-service program had an impact on your science teaching? How?
4. Has the program had an impact on how you teach courses other than science?
5. Do you think that the program will have a sustained impact on your science teaching?
6. How have students responded to the suggested language practices and strategies?
7. Have the perceptions of students with regard to reading and writing changed over the duration of the program? Give specific examples to illustrate your views.
8. How often have the students engaged in peer-group collaboration in your science class?
9. Is this more or less often than before the in-service program?
10. In what kinds of classroom activities did you use peer-group collaboration? Was it always effective?
11. How often have the students read texts in your science class?
12. Is this more or less often than before the in-service program?
13. How often have the students read texts, other than the textbook, in your science class?
14. Is this more or less often than before the in-service program?
15. Can you give us examples of the kinds of texts that students read in your science class?
16. How often have the students written texts in your science class?
17. Is this more or less often than before the in-service program?
18. Can you give us examples of the kinds of texts that students produced in your science class?
19. What are your personal goals going forward related to the in-service program on language and science?
20. What are some of the obstacles preventing you from implementing some of the practices or strategies presented during the in-service program?