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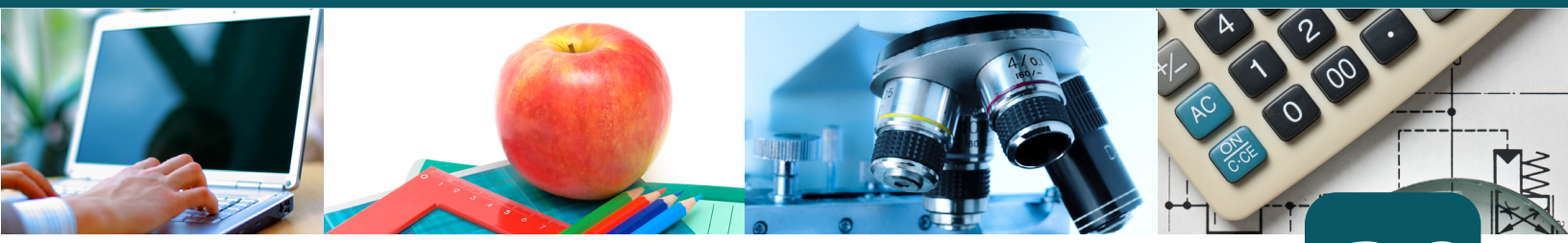

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Changing Attitudes: Are High School Students More Passionate about Science?

According to the Organisation for Economic Co-operation and Development (OECD), the sciences are less and less popular among students in the majority of member countries (OECD, 2017). This disinterest in science raises issues for an innovative and competitive economy (Statistics Canada, 2017; Conference Board of Canada, 2019). Beyond career choice, fostering and maintaining interest in science also helps create greater motivation and citizen engagement in research contexts, the demand for which is growing. Interest in science is also a school and teaching issue, as it is linked to success in scientific fields (Potvin and Hasni, 2014).

The Programme for International Student Assessment (PISA), conducted among 15-year-old students in 2006 and 2015, offers measurements of interest, enjoyment, and motivation in science. These aspects of attitude toward science can be used to analyze relationships with Canadian students' science scores. Although some studies demonstrate a high positive association between interest in science and academic achievement in science, Potvin and Hasni (2014) write that the relationship between these variables is complex. Fensham (2007), looking at the assessments at a large scale, indicates that achievement in a scientific domain does not necessarily correlate with interest. Among attitudinal factors, Lam and Lau (2014) identified enjoyment as one of the primary predictors of science achievement among students in Hong Kong. Finally, intrinsic motivation appears to positively influence academic achievement, including in science courses, while the effects of extrinsic motivation are not as clear (Chedru and Équipe PICAR-T, 2013). This paper will examine and compare attitudes of 15-year-old students toward science across Canadian provinces to verify whether attitudes towards science have changed, and whether there has been an effect on performance.

Research brief developed for the Council of Ministers of Education (CMEC) by
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Interest in science, enjoyment of learning science, and instrumental motivation

PISA indices of attitude are created using responses from students to four or five items in the Student Questionnaire. The indices are standardized so that the mean of the OECD student population is zero and the standard deviation is one. Negative values in an index do not imply that students responded negatively to the items, but that their answers are less positive than the average of all students in OECD countries. Scales for enjoyment of learning science and instrumental motivation were defined in a way that facilitates comparison of the 2015 values against 2006 values (OECD, 2016).

Science performance in PISA

Science performance is based on the scientific literacy assessment. Scientific literacy is "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (OECD, 2017, p. 22). PISA scores for science performance are expressed using a standardized scale with an average score of 500 for OECD member countries and a standard deviation of 100. This average was established in 2006, the first year where scientific literacy was the major domain of assessment, and it was re-established at 493 points in 2015.

Interest in broad science topics

According to Krapp and Prenzel (2011), interest in science is the result of a specific relationship, linked to values and emotions, between a person and an object (i.e., a concrete thing, a subject, or an abstract idea). In 2015, PISA modelled an indicator of interest using five items related to specific science topics: the biosphere; motion and forces; energy and its transformation; the universe and its history; and how science can help us prevent disease.

Provincial averages for the broad science topics indicator, shown in Table 1, are near the OECD average and all positive, which indicates that students had slightly more positive responses than the average of students in OECD. However, students in New Brunswick, Manitoba, and Saskatchewan responded less positively to the items compared to the Canadian average, while students in Alberta responded more positively. A higher index can be linked to interest in more science topics and/or greater interest in science topics.

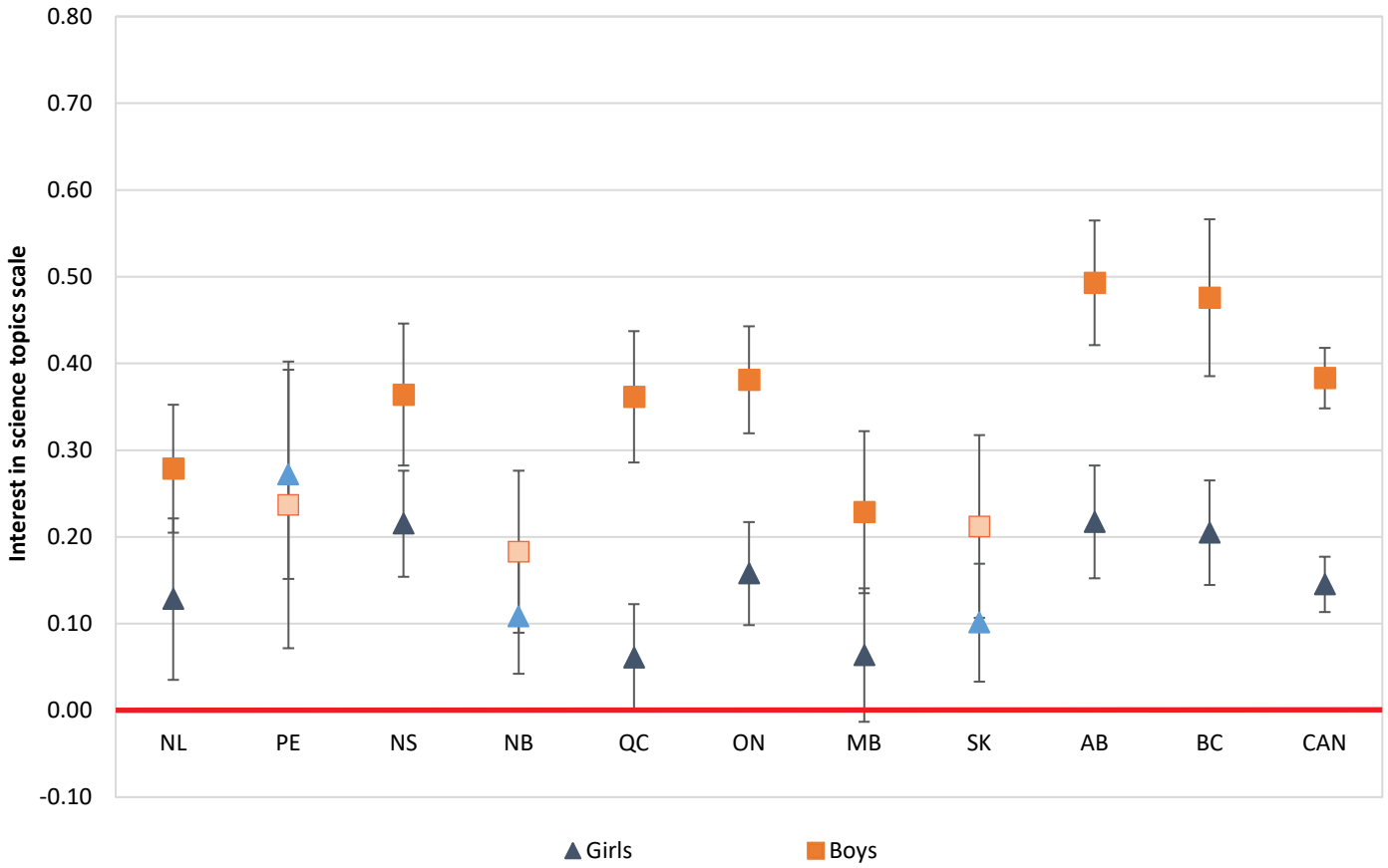
TABLE 1 Index of interest in broad science topics in PISA 2015

Province	Provincial average		French-language system		English-language system	
	Index score	Standard error	Index score	Standard error	Index score	Standard error
NL	0.20	0.03	--	--	--	--
PE	0.25	0.05	--	--	--	--
NS	0.29	0.03	0.19	0.14	0.29	0.03
NB	0.15**	0.03	0.24*	0.05	0.11*	0.04
QC	0.20	0.03	0.22*	0.03	0.08*	0.04
ON	0.27	0.02	0.27	0.05	0.27	0.03
MB	0.15**	0.03	0.28	0.08	0.14	0.04
SK	0.16**	0.03	--	--	--	--
AB	0.35**	0.03	0.42	0.20	0.35	0.03
BC	0.34	0.03	0.41	0.05	0.34	0.03
CAN	**0.26**	**0.01**	**0.23**	**0.03**	**0.27**	**0.01**

*Significant difference within Canada or province.
**Significant difference compared to Canada.
Note: Since Newfoundland and Labrador, Prince Edward Island, and Saskatchewan did not oversample students by language, only results for English-language schools are available for these provinces.

In New Brunswick and Quebec, there is a statistically significant difference between language systems compared to the seven provinces where the sample permitted this type of analysis. An analysis of the index based on the gender of the students reveals statistically significant differences in the majority of provinces, with boys responding more positively to the items of this index (Figure 1). In their review of scientific literature, Osborne, Simon, and Collins (2003) identify a student's gender as the most influential factor on interest in science.

FIGURE 1 **Index of interest in science topics in PISA 2015, by gender**



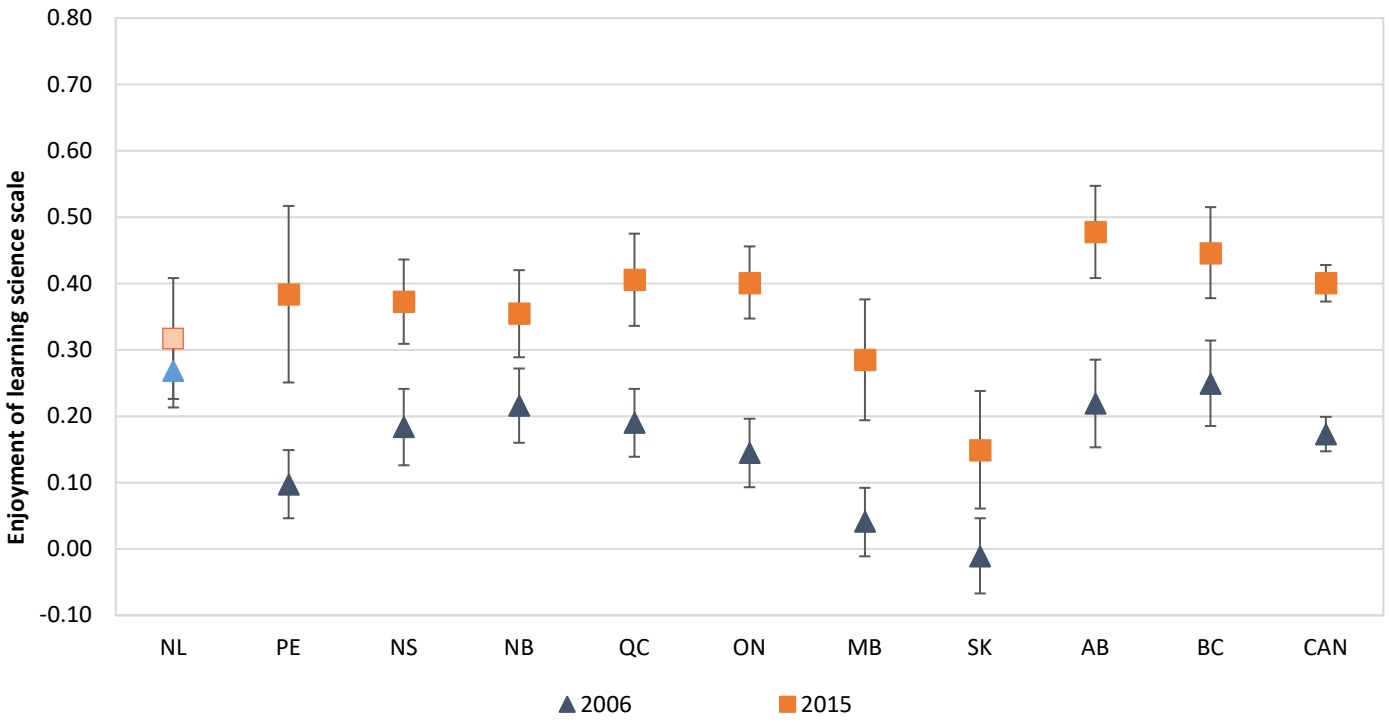
Note: Darker shades denote significant difference between girls and boys within a province. Red line denotes the OECD average.

Enjoyment of learning science

Wigfield and Eccles (2000) differentiate the concept of interest from the enjoyment of learning. The latter can occur for many reasons, including interest in the subject area. Enjoyment and other emotions in the school context have been the subject of many studies (Ainley and Ainley, 2011; Cuisinier and Pons, 2011; Pekrun, Goetz, Frenzel, Barchfeld, and Perry, 2011). Pekrun et al. (2011) have demonstrated a statistically significant difference between genders, with girls reporting more enjoyment in the classroom than boys.

PISA modelled an indicator of enjoyment of learning science using five items, such as "I generally have fun when I am learning broad science topics," to which students had to indicate how much they agreed. In all the provinces, students responded more positively to the items in these indices in 2015 than in 2006. The differences are all statistically significant, except in Newfoundland and Labrador. In PISA 2006, the indices for Manitoba and Saskatchewan were below the Canadian average, while the index for Newfoundland and Labrador was above the average. In 2015, only the index for Saskatchewan was significantly lower than the Canadian average.

FIGURE 2 **Index of enjoyment of learning science in PISA 2006 and PISA 2015**



Note: Darker shade denotes significant difference between 2006 and 2015 within Canada or a province.

This increase seems inconsistent with the worldwide decline in interest in the study of science. Some studies on science education make a distinction between interest in science in general and interest in "school" science (Osborne et al., 2003), where science in general is perceived more positively than school science. It appears plausible that students, in the context of a large-scale assessment, may have answered questions about enjoyment of learning science while thinking about the general science that surrounds them—for example, what they perceive to be associated with the technological developments of personal computers and telecommunications. Just as with interest in science in general, it's possible that their answers about enjoyment are less linked to a specific academic discipline or activity and, accordingly, more positive.

At the OECD level, just like at the Canadian level, a majority of students reported that they enjoyed learning science, but boys tended to report so more than girls. In PISA 2015, half of the provinces had a statistically significant difference among averages for girls and boys on the index of enjoyment of learning science (Table 2). Work by Pekrun et al. (2011) has demonstrated that girls report more enjoyment in the classroom. However, enjoyment of learning science as defined by PISA, which is broader than the classroom science context, does not reflect this trend. In terms of language systems, New Brunswick, Quebec, and Manitoba show a statistically significant difference favouring students in French-language systems.

Table 2 **Indices of enjoyment of learning science in PISA 2015, by gender and language system**

Province	Average indices by gender				Average indices by language system			
	Girls		Boys		French-language system		English-language system	
	Index score	Standard error	Index score	Standard error	Index score	Standard error	Index score	Standard error
NL	0.23*	0.06	0.41*	0.06	--	--	--	--
PE	0.33	0.09	0.43	0.10	--	--	--	--
NS	0.37	0.04	0.38	0.05	0.25	0.08	0.38	0.03
NB	0.38	0.04	0.33	0.05	0.48*	0.06	0.31*	0.04
QC	0.30*	0.04	0.52*	0.04	0.43*	0.04	0.25*	0.04
ON	0.33*	0.03	0.47*	0.04	0.34	0.05	0.40	0.03
MB	0.28	0.06	0.29	0.05	0.45*	0.07	0.27*	0.05
SK	0.09	0.06	0.20	0.05	--	--	--	--
AB	0.40*	0.05	0.56*	0.04	0.43	0.30	0.48	0.04
BC	0.37*	0.05	0.53*	0.04	0.54	0.10	0.45	0.04
CAN	**0.33***	**0.02**	**0.48***	**0.02**	**0.42**	**0.04**	**0.40**	**0.02**

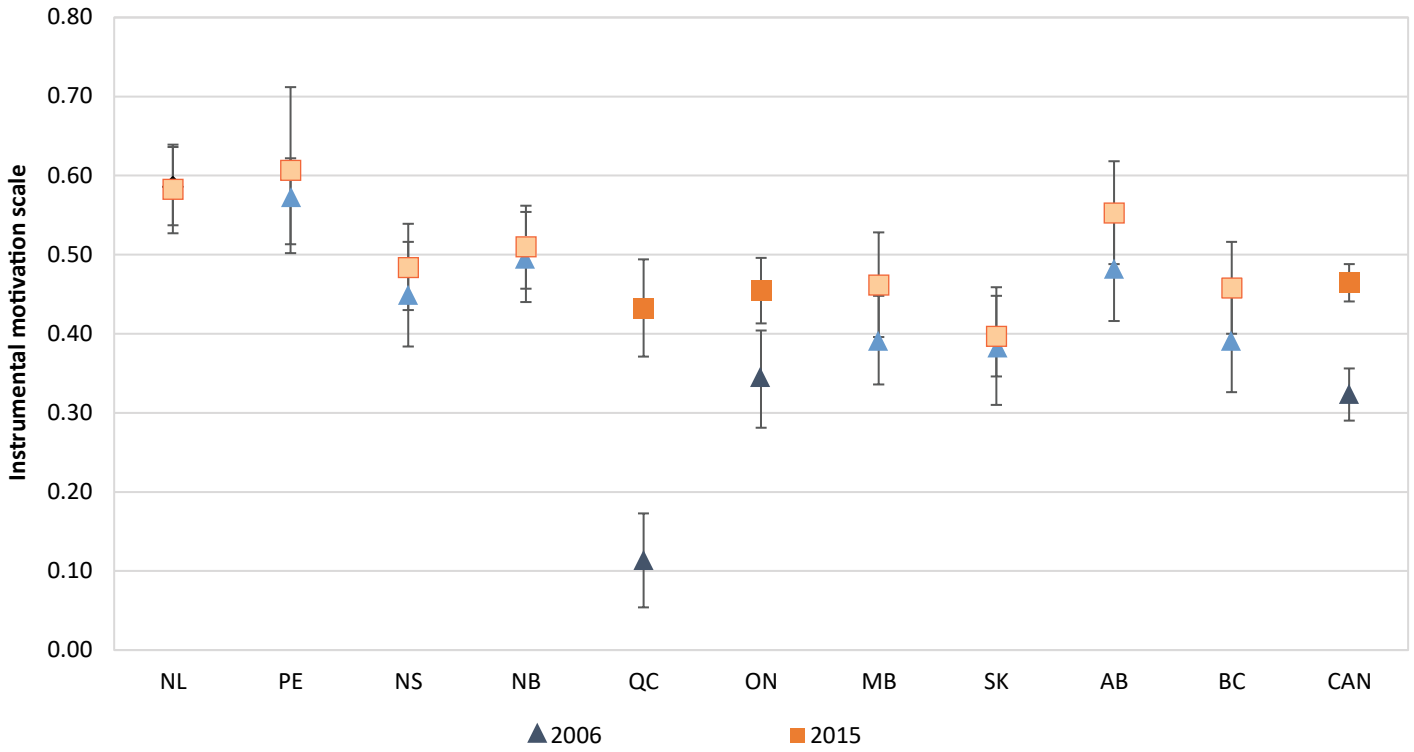
*Significant difference within Canada or province.
Note: Since Newfoundland and Labrador, Prince Edward Island, and Saskatchewan did not oversample students by language, only results for English-language schools are available for these provinces.

Instrumental motivation

Potvin and Hasni (2014) indicate that motivation generally includes the idea of a goal, with an intrinsic origin (most often) or an extrinsic origin that steers the student's behaviour. Behaviours supported by intrinsic motivation turn out to be highly self-determined, and triggered by interest and the enjoyment of the activity itself. According to Osborne et al. (2003), girls appear to be more intrinsically motivated when choosing courses, while boys are more extrinsically motivated.

PISA modelled an extrinsic (or instrumental) motivation indicator using four items, such as "Making an effort in my school science subject(s) is worth it because this will help me in the work I want to do later on," to which the students had to indicate how much they agreed. Figure 3 shows the averages of the index as measured in 2006 and 2015, which remained stable in most of the provinces except Quebec, where there was a marked increase in instrumental motivation in 2015, and students in Newfoundland and Labrador and Prince Edward Island were positioned more positively than the Canadian average on the instrumental motivation scale.

FIGURE 3 Indices of instrumental motivation in PISA 2006 and PISA 2015



Note: Darker shade denotes significant difference between 2006 and 2015 within Canada or a province.

In PISA 2015, at the provincial level, students in Quebec's French-language system had statistically higher instrumental motivation than students in the English-language system. This was the only province with a statistically significant difference between language systems (Table 3). In Prince Edward Island, Nova Scotia, New Brunswick, and Saskatchewan, a statistically significant difference could be seen between girls and boys, as was the case globally across Canada. According to Osborne et al. (2003), there are observable differences between girls and boys in terms of motivation. However, no clear trend was revealed through the indices or the analysis of responses to items in the index of instrumental motivation.

Table 3 **Indices of instrumental motivation in PISA 2015, by gender and language system**

Province	Average indices by gender				Average indices by language system			
	Girls		Boys		French-language system		English-language system	
	Index score	Standard error	Index score	Standard error	Index score	Standard error	Index score	Standard error
NL	0.62	0.04	0.54	0.04	--	--	--	--
PE	0.74*	0.08	0.48*	0.08	--	--	--	--
NS	0.59*	0.04	0.38*	0.04	0.55	0.09	0.48	0.03
NB	0.61*	0.04	0.41*	0.04	0.60	0.05	0.48	0.03
QC	0.41	0.04	0.46*	0.04	0.45*	0.03	0.29*	0.03
ON	0.48	0.03	0.42	0.03	0.40	0.06	0.46	0.02
MB	0.50	0.04	0.42	0.04	0.46	0.05	0.46	0.04
SK	0.46*	0.04	0.34*	0.03	--	--	--	--
AB	0.59	0.04	0.51	0.04	0.40	0.26	0.55	0.03
BC	0.48	0.04	0.43	0.04	0.41	0.09	0.46	0.03
CAN	**0.49***	**0.02**	**0.44***	**0.02**	**0.45**	**0.03**	**0.47**	**0.01**

*Significant difference within Canada or province.
Note: Since Newfoundland and Labrador, Prince Edward Island, and Saskatchewan did not oversample students by language, only results for English-language schools are available for these provinces.

Association between indices of attitude and science performance

Figure 4 summarizes the associations between the dimensions of attitude and science scores in PISA 2015 in Canada. The data shows a high positive association between enjoyment of learning science and interest in broad science topics across all provinces. The positive associations are not quite as high between instrumental motivation and the two other attitudinal indices across all provinces. These associations are consistent, since interest, enjoyment, and motivation are factors that overlap with each other with varying significance, depending on the theory or empirical study consulted. For example, for Ryan and Deci (2000), enjoyment can trigger behaviours that support motivation; for Ainley and Ainley (2011), enjoyment and interest have complementary functions.

FIGURE 4 **Measurement of association between the dimensions of attitude and science scores in PISA 2015 in Canada**

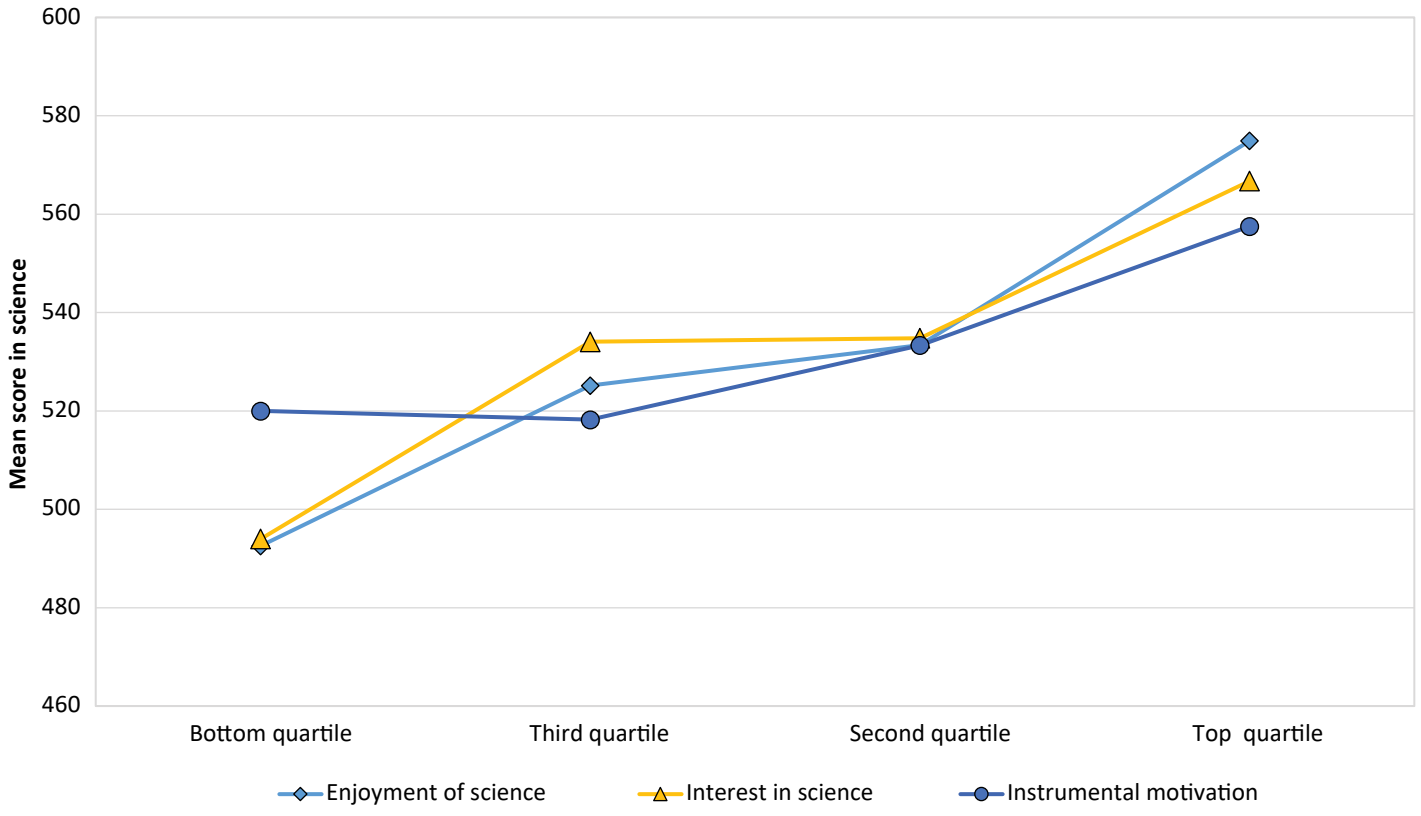
	Interest in science topics	Enjoyment of learning science	Instrumental motivation	Science score
Interest in science topics				
Enjoyment of learning science				
Instrumental motivation				
Science score				

Strong association Moderate association Weak association

There are also significant positive associations between the three indices of attitude and science performance; only the effect size changes. The association between science performance and enjoyment of learning science is moderately significant in the very large majority of the provinces. Science performance seems to be weakly associated with instrumental motivation, while the strength of the association with interest in broad science topics varies from weak to moderate across provinces. The association between interest and enjoyment is consistent with the works of Ainley and Ainley (2011). Among the indices of attitude, enjoyment of learning science has the strongest association with performance, which is consistent with the findings of Lam and Lau (2014)—even though these findings relate to students in Hong Kong, which has a population that is culturally different than the Canadian population.

In the upper quartiles, enjoyment of learning science is associated with higher scores, followed by interest, and then instrumental motivation (Figure 5).

FIGURE 5 **Science scores associated with each quartile for interest, enjoyment, and motivation in PISA 2015, Canada**



Implications

Students' positive attitudes toward science help foster curiosity, and a desire to understand the role of science in a democratic society. They are also important for success and the career choice process. It would be useful to understand how factors like interest in science topics, enjoyment of learning science, and instrumental motivation are related to each other, how these variables change over time, and how they might be associated with science performance. In addition, exploring how enjoyment is related to science and school science seems appropriate, considering the increase in the index of enjoyment of learning science and its contribution to science performance.

Measurement differences observed across the provinces could have been caused by different curricula and cultural differences. The influence of the curriculum on students' attitudes toward science remains widely unknown (Osborne et al., 2003). At the end of the 1990s, pan-Canadian reflection on science teaching led to the development of a framework for the basic elements required in science curricula in Canada (Council of Ministers of Education, Canada, 1997). The framework was designed for developing science literacy from Kindergarten to the end of high school in a more standardized way across Canada. Each province maintains its jurisdiction over education, and each province has its own curriculum based on its own system organization. Large-scale assessments in which provinces participate offer valuable points of comparison for evaluating and improving education systems in the Canadian, North American, and international contexts.

REFERENCES

Ainley, M., & Ainley, J. (2011). A Cultural Perspective on the Structure of Student Interest in Science. *International Journal of Science Education, 33*(1), 51–71. https://doi.org/10.1080/09500693.2010.518640

Chedru, M., & Équipe PICAR-T. (2013). Prédire la performance académique: les éclairages apportés par les caractéristiques individuelles de la motivation. *Actes du congrès de l'AGRH, Paris*, 15. https://www.agrh.fr/assets/actes/2013-chedru.pdf

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155–159. https://doi.org/10.1037/0033-2909.112.1.155

Conference Board of Canada, the. (2019, January 24). Graduates in Science, Math, Computer Science, and Engineering. https://www.conferenceboard.ca/hcp/provincial/education/sciencegrads.aspx

Council of Ministers of Education, Canada. (1997). *Pan-Canadian Protocol for Collaboration on School Curriculum. For use by Curriculum Developer*. http://science.cmec.ca/framework/

Cuisinier, F., & Pons, F. (2011). *Émotions et cognition en classe*. 14. https://hal.archives-ouvertes.fr/hal-00749604/document

Fensham, P. J. (2007). Interest in Science: Lessons and Non-lessons from TIMSS and PISA. In R. Pintó & D. Couso (eds), *Contributions from Science Education Research* (pp. 3–10). https://doi.org/10.1007/978-1-4020-5032-9_1

Krapp, A., & Prenzel, M. (2011). Research on Interest in Science: Theories, Methods, and Findings. *International Journal of Science Education, 33*(1), 27–50. https://doi.org/10.1080/09500693.2010.518645

Lam, T. Y. P., & Lau, K. C. (2014). Examining Factors Affecting Science Achievement of Hong Kong in PISA 2006 Using Hierarchical Linear Modeling. *International Journal of Science Education, 36*(15), 2463–2480. https://doi.org/10.1080/09500693.2013.879223

Lamy, P. (2017). LAB-FAB-APP. Investing in the European Future We Want. *European Commission*. https://data.europa.eu/doi/10.2777/477357

Organisation for Economic Co-operation and Development (OECD). (2016). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. https://doi.org/10.1787/9789264266490-en

Organisation for Economic Co-operation and Development (OECD). (2017). *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving*. https://doi.org/10.1787/9789264281820-en

Organisation for Economic Co-operation and Development (OECD). (2018). *Education at a Glance 2018: OECD Indicators*. https://doi.org/10.1787/eag-2018-en

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards Science: A Review of the Literature and its Implications. *International Journal of Science Education, 25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199

Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P., & Perry, R. P. (2011). Measuring Emotions in Students' Learning and Performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary Educational Psychology, 36*(1), 36–48. https://doi.org/10.1016/j.cedpsych.2010.10.002

Potvin, P., & Hasni, A. (2014). Analysis of the Decline in Interest towards School Science and Technology from Grades 5 through 11. *Journal of Science Education and Technology, 23*(6), 784–802. https://doi.org/10.1007/s10956-014-9512-x

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology, 25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Statistics Canada. (2017). *Education in Canada: Key results from the 2016 Census* (No. 3901) https://www150.statcan.gc.ca/n1/en/daily-quotidien/171129/dq171129a-eng.pdf?st=rLVsVBHw

Wigfield, A., & Eccles, J. S. (2000). Expectancy–Value Theory of Achievement Motivation. *Contemporary educational psychology, 25*(1), 68–81. https://doi.org/10.1006/ceps.1999.1015