Trajectory of Learning Experience based on the Performance of Canada's Youth in Mathematics

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Abstract

This study empirically evaluated the learning experience of Canadian youth in mathematics, based on existing theoretical tenets, to explore a conceptual model that depicts two major orientations: one is the *internal aspects*, which focus on how the students feel; and another is *external aspects*, which focus on how the students behave. An imperative question underpinning this research involves examining different untested trajectories of learning experience in Mathematics that could elucidate and predict individuals' mastery-approach goals. The data from the *Organisation for Economic Co-operation and Development* (OECD) Programme for *International Student Assessment* (PISA) 2012 surveys comprises participants who are 15-year-old Canadian students from different provinces, investigating how the factors of learning approaches, learning environments, and participants' familiarity affect their development of skills and learning attitudes, both at home and at school in mathematics. Path analytical procedures are applied to test the hypothesized relationships, and certain notable findings would impact mediating mechanisms while remarkable trajectories would inform complete pedagogical practices. Particularly, this research is significant for its un-exploratory nature. The Path Analysis offers visions of the relationships between the internal and external aspects, and the relationships between the elements in those same internal and external aspects. The contribution of this study is that the results/findings could support policy targets by establishing measurable goals for consideration and implementation, assist in the building of trajectories for reform, as well as notify all stakeholders such as educators, researchers, parents, governments, and policy makers about the importance of understanding individuals' academic and learning patterns, as the researcher contends.

Introduction

All stakeholders, such as educators, researchers, parents, governments, and policy makers need to discern how the education systems prepare students for real-life situations. A number of countries monitor students' learning to evaluate their learning outcome; however, few measurable and realizable assessments could be used as a reference (Coates & Richardson, 2012; Finn, 1990; Slavin & Tanner, 1979; Spady, 1982; Spence & Helmreich, 1983). Particularly, the comparative international assessments stretch out the national landscape and augment a larger context, which compare and interpret national performance. These assessments would offer what are potential solutions in education in terms of the quality of edifying outcomes and also provide equity in the distribution of learning opportunities. Hence, to investigate the trajectory of learning experience would support policy targets, institute measurable goals, and assist and even reform the educational system in question. In addition, to compare the assessments would assist countries in better understanding the risks and challenges of student learning, examining their relative strengths and weaknesses as well as monitoring progress.

The present study sets out to explicitly examine the extent to which academic outcomes track with students' learning experiences in mathematics in the Canadian context, and this can be obtained from the data produced by the *Organisation for Economic Co-operation and Development* (OECD) *Programme for International Student Assessment* (PISA) surveys. The surveys, by participants who were 15-year-old students from over 65 countries, investigated how well those students were prepared to face the difficulties and challenges of their future during compulsory education. The three aspects of assessment are reading literacy, mathematical literacy, and scientific literacy. This study scrutinized the PISA 2012 assessment, which covered three domains of knowledge; it examines students' skill in reading, mathematics, and science, with a particular focus on mathematical literacy. Furthermore it offers insights into how the factors involved in learning approaches, learning environments, and participants' familiarity, affect their development of skills and learning attitudes, both at home and at school. The researcher adopted the Canadian students (n=21,544) as a sample case, since the original data contains a large dataset. The OECD launched the PISA in 1997 to study the cross-national comparable evidence on student learning performance (OECD, 2014a). An internationally agreed upon common framework includes PISA obligating governments to monitor the outcomes of education systems and measure student performance on a regular basis. This facilitates opportunities to connect the findings with the implementation of educational goals in addition to offering an innovative approach that reflects students' skills and looks at how these skills are relevant to adult life.

Age 15, is a crucial age in the preparation of young people to face the challenges which they may encounter in future life, due to the fact that students are approaching the end of compulsory education in most countries, such as Canada, Germany, Australia, Japan, Korea, Finland, and other countries (Aho, Pitkänen, & Sahlberg, 2006; Brochu, Deussing, Houme, & Chuy, 2013). Mathematical performance is examined in this research to try and predict and explain the various phenomena relevant to groups of students aged 15 years in Canada who interpret mathematics in various contexts and express mathematics regularly as it is employed in the world. The OECD provides a research platform and PISA provides participating governments with all of the scientific expertise needed to explore this issue, which measures 15-year-old students' knowledge, skills, and learning attitudes at both the national and international levels. Tables 1 and 2 below, illustrate the students' mean score of mathematics performance, which was ascertained using surveys conducted by PISA in 2012, and by those countries who joined OECD for the investigation (OECD, 2014c).

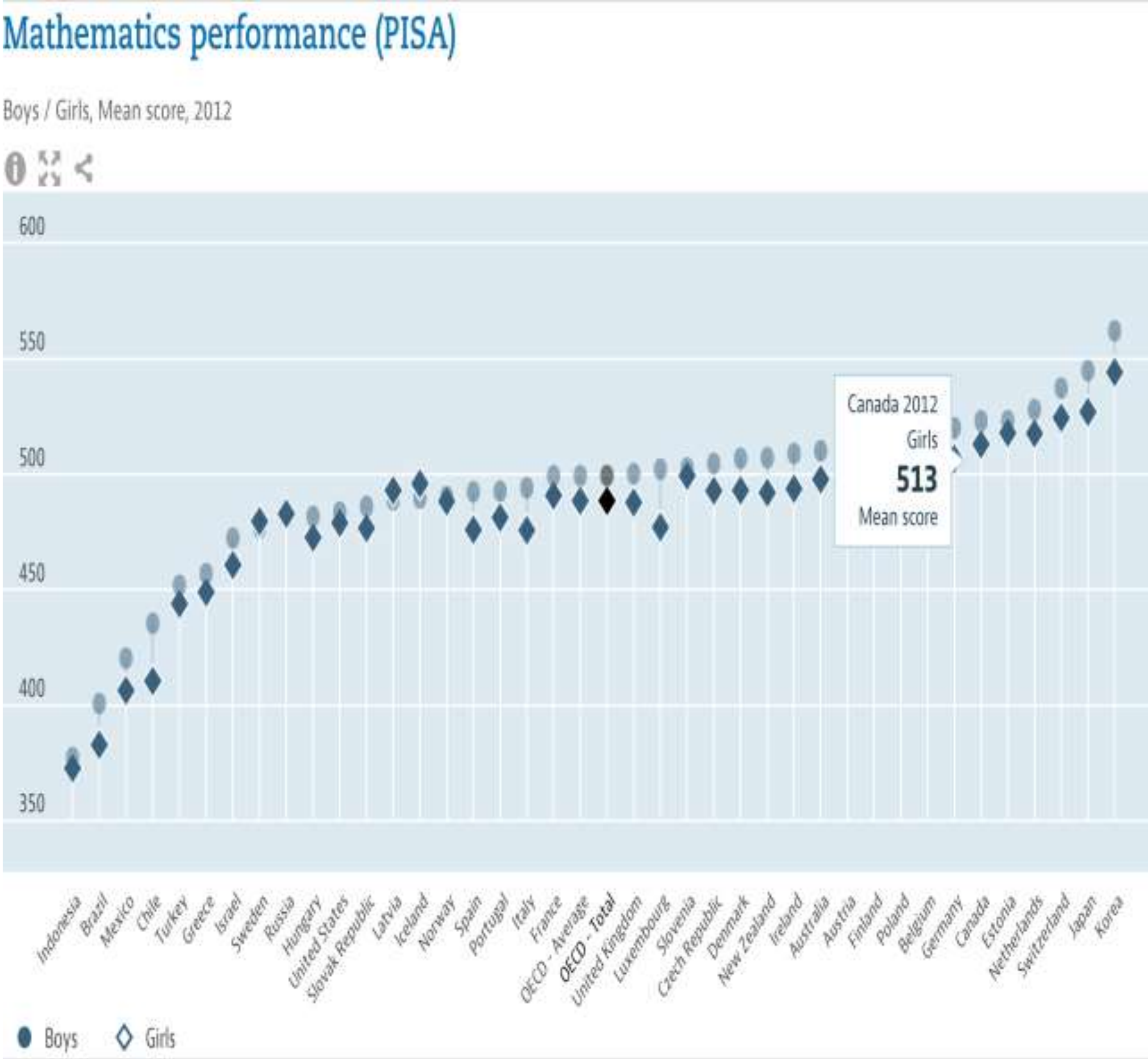

Table 1. Mathematics performance (PISA) girls, mean score, 2012

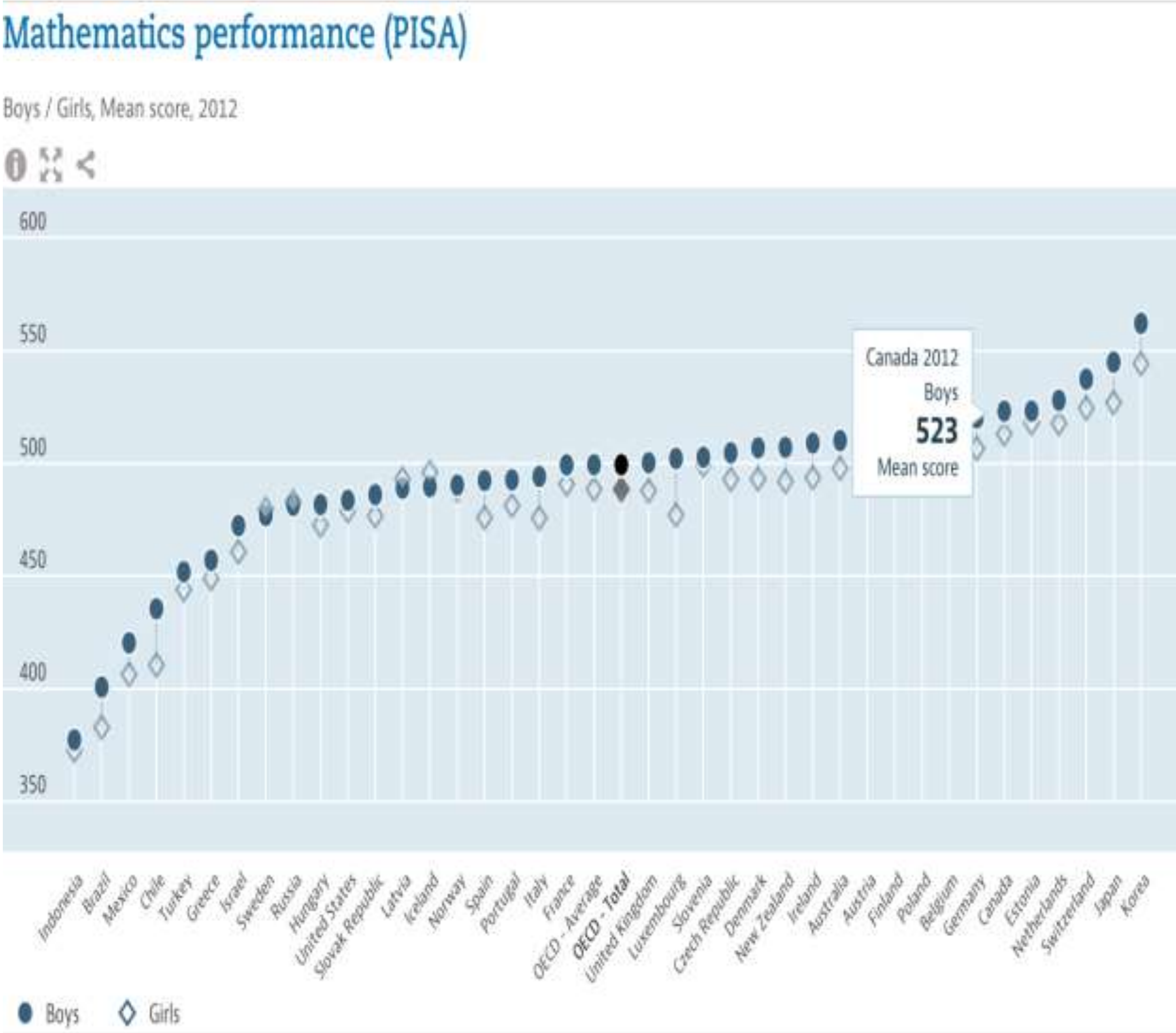

Table 2. Mathematics performance (PISA) boys, mean score, 2012

Literature review

This study entails the research of students' learning experiences, in particular 15-year-olds actively participating in their school and social milieus, specifically by measuring knowledge, skills, and learning attitudes regarding their mathematical literacy. The existing literature on the dimensions of career interests, goals, and choice regarding further education are scrutinized by certain researchers, educators, and scholars, such as Luzzo, Hasper, Albert, Bibby, and Martinelli (1999) who investigated the effect of both mathematical learning experiences and the performance accomplishments on participants' assessments of vocational interests, career aspirations, and career choice action through pre- and post-treatment, applying theoretical and counseling implications. This research also links to the Model of achievement-related choices by Eccles, Barber and Jozefowicz (1999) who point out that students who are interested in mathematics and science demonstrate preferences for certain occupations, and students who enjoy learning mathematics and science mostly aspire to careers as professionals. Leading gender research by Vale and Leder (2004) and Bartholomew (2004), point to gendered differences in mathematics achievement. They argue from the liberal feminist theory perspective and also discuss the gender gap for achievement, which is similar to the research findings of Fennema, Forgasz, Leder, Kloosterman, and Vale (Fennema, 1995; Forgasz, 2004, 2005; Forgasz, Leder, & Kloosterman, 2004; Forgasz, Leder, & Vale, 2000; Leder & Forgasz, 1992) where they examined a study of the gender gap among students who participate in the Australian Mathematics Competition. These researchers sought to explain the relationships between mathematics learning experiences and aspirations for work; ascertaining mathematical performance impacted students' perspectives.

Certainly, the gender issue would be one of the factors encompassing the clarification of specific motivational variables; however, psychosocial factors may also account for mathematical learning, mainly in the areas of cognition and motivation. Why do some youth display a posture of disengagement and maladaptive practices when they learn mathematics? Psychosocial factors would impact students' learning in mathematics, but unfortunately, few of these studies trace the discourse of adolescents' psychosocial levels using methodological insights into youths' learning processes in mathematics. For instance, Leone, Wilson and Mulcahy (2010) contributed research focused on youth who encounter neglect, are delinquent, or are at risk when they learn mathematics, and they offer a strategy guide to improve educational programming. Another notable work from Asera and Fong (2010) explored psychological research focusing on learning theory and approaches in order to support students' academic success for learning mathematics; they present a program — *Academic Youth Development* (AYD) — as an initiative to put motivational theories to practice.

In sum, the process of learning in mathematics has been portrayed by a number of researchers, educators, investigators, and philosophers, which has prompted the focus of this research which is to ask: what are the best models for students learning in mathematics to assist them with academic success or making the choice for a potential career path? This research analyses the impact of enactive learning experiences in relation to this question.

Methodology

An examination of students' learning experiences in mathematics reflects two important postulations: the impact of the enactive learning experience on the articulation of:
(1) *internal aspects*, which means how students feel and includes three variables: *maths anxiety, instrumental motivation,* and *subjective norms*;
(2) *external aspects* which relates to how the students behave and includes three variables: *maths behavior, maths work ethics,* and *truancy.*

This examination spans conceptual postulations and offers methodological insights into the operational nature and patterns in associations between these theoretical orientations based on educational psychology.

In the field of educational psychology there are various types of learning theories. This research addresses two dominate schools of learning theories that were introduced in the twentieth century; one is the school of *cognitive psychology* and the other is the school *of behavioral psychology*.

(1) The cognitive psychological perspective, as the basic school of learning theories, affords a theoretical rationale such as that of the Swiss psychologist Jean Piaget who

contributed a formally evolving four stages of intellectual development — sensorimotor, preoperational, concrete operational, and formal operational — in learning situations (Ginsburg, & Opper, 1969). Piaget's four stages stress the fact that youth's expressions differ from adults, and this would be the essence of how students feel when they are learning mathematics. Piaget's concept is beyond just the learning of mathematics, since Zoltan Dienes espouses his idea and proposes another cognitive view of mathematics learning by encouraging active youth engagement with concrete learning materials as an art form in order to support the student having a *better* performance. Four dynamic principles are associated with students' performance: the dynamic principle, the perceptual variability principle, the mathematical variability principle, and the constructivity principle; the implications of these four principles expand the individualized learning of students with different learning abilities in mathematics (Noddings, 1990; Reys & Post, 1973).

(2) As the foremost of behavioral psychology contributions, the neo-behavioral perspective mainly considers the behavioral response of the learner, and one of the proponents of this theory is Robert Gagné. Gagné postulates five categories of capabilities which embrace intellectual skills, cognitive strategies, verbal information, motor skills, and attitudes, and can explain the desired capabilities in terms of what the students can do (Gagne, 1985; Russell & Ginsburg, 1981, 1984; Wearne & Hiebert, 1988). Consequently, this concept determines the logical content prerequisites necessary in order to classify students' capabilities for learning mathematics.

Definitions of the domains

Mathematical literacy

In this paper, the term mathematics refers to *mathematical literacy*, which articulates how students engaging in mathematics actively prepare for their future, and the data is adopted from PISA; also, the term mathematics signifies the degree to which the student can demonstrate their capacity to apply mathematical contents and concepts. In the document *PISA 2012 Assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy*, it clearly states:

> *Mathematical literacy: An individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens*. (p. 25)

Data sample

The purpose of this paper is to apply the SPSS computer program in analyzing the dataset from the OECD Programme for International Student Assessment (PISA) surveys with the corresponding codebook to test separate hypotheses. A cross-sectional design in the PISA 2012 assessment is sampled using the data from approximately 20,000 students who were 15 years old from more than 850 schools in British Columbia, Alberta, Manitoba, Ontario, Quebec, New Brunswick, and Nova Scotia. This study adopted the PISA 2012 assessment investigating randomly selected students' performances in reading, mathematical, and scientific literacy from each of the designated schools and in terms of the aim of PISA, which is to assess students' skills and knowledge, and determine whether they are prepared for full participation in society by the end of compulsory education.

The analysis of the data in this study is based on the various information that has been provided by PISA 2012, such as the codebook, the data analysis manual, and the assessment framework. PISA 2012 has thirteen different test booklets for the students to be randomly assigned to; however, the major domain was mathematics. The analysis in this paper is focused on the issue relating to students' competencies in the key subject areas of mathematics, both in school and non-school contexts. While over 66 countries participated in PISA 2012, and up to 10,000 students were involved in each country, in this particular assessment, only Canadian students (*n=21,544*) were considered due to the limited scope of this research.

Key factors affecting the internal and external aspects

This section will apply *Path Analysis* to measure how a complex set of variables, which includes all variables that this research proposes (the internal and external aspects), might be interrelated.

Path Analysis

Path Analysis is under the umbrella of *Structural Equation Modelling* (SEM), and this form of Structural Equation Modeling was invented by the profound geneticist Sewall Wright and developed in 1918, as well as deeply explored in the 1920s (Wright, 1921, 1934). The definition of Path Analysis, as the scholars Foster, Barkus, and Yavorsky (2006) point out, is that it "makes use of regression analysis to look at the relationship between variables" and also that "the primary difference between the techniques is that path analysis graphically and explicitly looks at causal factors" (p. 89).

Path Analysis is a straightforward extension of multiple regression. The aim of Path Analysis is to provide estimates of the magnitude and significance of hypothesized causal connections between sets of variables. It determines the total effect of one variable over the other one. A Vector diagram, also known as a path diagram, is used to explain such causal connections. A Path diagram consists of an input path diagram and an output path diagram. The input path diagram is the one that is drawn first to help plan the analysis and represents the causal connections that are predicted by the hypothesis, while the output path diagram represents the results of a statistical analysis, and measures the effect quantitatively.

Path Analysis can indicate the relative importance (and significance) of various paths, and this may have implications for the plausibility of pre-specified causal hypotheses. The relative sizes of path coefficients in the output path diagram may tell which path is better supported by the data. Based on the output path diagram, the total effect of one variable (e.g., gender, in the current study) on the other variable (e.g., truancy, in the current study) can be computed. That's why Path Analysis is the preferred analysis in this study.

Hypotheses

H1: It is proposed that Gender (dummy coded) will be positively related to an individual's incidence of Truancy. Earlier research indicated that male students tended to have a higher incidence of truancy than females (Moseki, 2004).

H2: It is proposed that subjective norms will inversely affect Truancy.

H3: It is proposed that Mathematics Behaviour will be inversely related with Truancy. That means a student with better Mathematics Behavior will have lower incidence of truancy.

H4: It is proposed that Mathematics Motivation will inversely affect Truancy. This means truancy can be lowered by enhancing mathematics motivation.

H5: It is proposed that Mathematics Anxiety will be positively related to an individual's incidence of Truancy. That means if the mathematics anxiety is higher, then the truancy incidence will go up.

Measures

Predictor variables

Gender: Gender was originally coded as 1 = male and 2 = female. Female was recoded to 0 for this dichotomous variable. There were 10,601 male and 10,943 female students in the chosen sample.

Subjective Norms: This variable was recorded and treated as a continuous variable for the purpose of this analysis.

Mathematics Anxiety: This variable was recorded and treated as a continuous variable for the purpose of this analysis.

Mathematics Behaviour: This variable was recorded and treated as a continuous variable for the purpose of this analysis.

Outcome variables

Truancy: "Skipping [the] whole school day" was used for this variable.

Results

The Pearson correlation (r) was used in this analysis to determine the correlation between the dependent variable of Truancy and the independent variables of Gender, Subjective Norms, Mathematics Anxiety, Mathematics Motivation, and Mathematics Behaviour (see Table 3). Table 3 reveals that almost all of the scores are significant to an alpha level of 0.05. The highest negative correlation exists between Mathematics Motivation and Truancy, while the highest positive correlation exists between Mathematics Anxiety and Truancy.

Table 3: Truancy – Correlations

		ST09Q01 Truancy - Skip whole school day	GENDER Gender (dummy coded)	ANXMAT Mathematics Anxiety	ANCINSTM Instrumental Motivation for Mathematics (Anchored)	SUBNORM Subjective Norms in Mathematics	MATBEH Mathematics Behaviour
ST09Q01 Truancy - Skip whole school day	Pearson Correlation	1					
	Sig. (2-tailed)	.					
	N	21011					
GENDER Gender (dummy coded)	Pearson Correlation	.015(*)	1				
	Sig. (2-tailed)	.027	.				
	N	21011	21544				
ANXMAT Mathematics Anxiety	Pearson Correlation	.100(**)	.165(**)	1			
	Sig. (2-tailed)	.000	.000	.			
	N	13872	13983	13983			
ANCINSTM Instrumental Motivation for Mathematics (Anchored)	Pearson Correlation	-.105(**)	.015	-.247(**)	1		
	Sig. (2-tailed)	.000	.202	.000	.		
	N	6854	6911	6876	6911		
SUBNORM Subjective Norms in Mathematics	Pearson Correlation	-.112(**)	-.019(*)	-.088(**)	.262(**)	1	
	Sig. (2-tailed)	.000	.023	.000	.000	.	
	N	13950	14100	6965	6872	14100	
MATBEH Mathematics Behaviour	Pearson Correlation	-.079(**)	-.120(**)	-.154(**)	.165(**)	.291(**)	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.
	N	13915	14068	6948	6852	14001	14068

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

Path analysis results

The relationships are indicated by the path coefficients in Figure 1 to “show the effect of the independent on the dependent variables and also any relationship between independent variables” (Foster, Barkus, & Yavorsky, 2006 p. 89). This approach to analysis was selected due to the complexity of Truancy, and it enables us to identify correlations between independent / predictor variables. It also allows us to examine the causal effects of various predictor variables on an outcome variable. In this case, the predictor variables (Xs) are Gender, Subjective Norms, Mathematics Anxiety, Mathematics Motivation, and Mathematics

Behaviour. Of these variables, the exogenous variable is gender only. The outcome variable (Y) in the path analysis is Truancy; the remaining four variables (Subjective Norms, Mathematics Anxiety, Mathematics Motivation, and Mathematics Behaviour) are intervening variables that cause indirect effects on the outcome variable.

For the sake of establishing the path diagram, regression between variables on the input path diagram was computed using the SPSS simple regression program. The Standardised Regression Coefficients (Beta weight) were used as the path coefficient. The resulting path diagram is as follows:

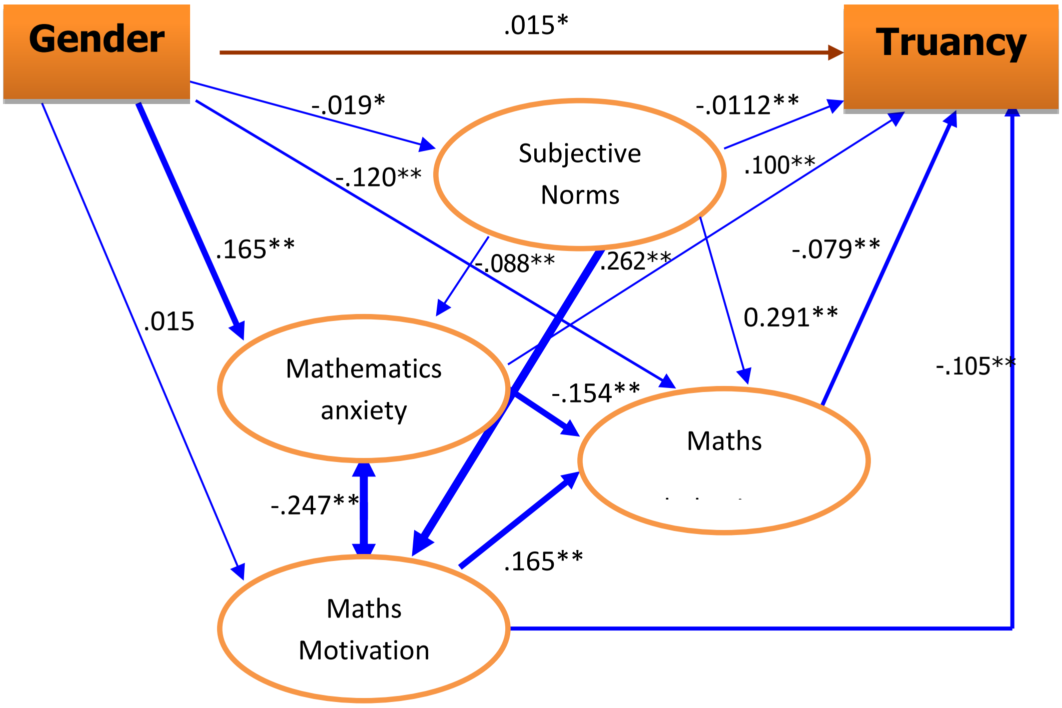

Figure 1: Path diagram

Decomposition Effects for Truancy

Based on the above diagram, the total effect of Gender on Truancy can be computed as follows:

Direct effect: 0.015

Indirect effect:

A. through Subjective Norms (-0.019 x –0.0112) = 0.000213
B. through Subjective Norms and Mathematics Behaviour (-0.019 x 0.291 x –0.079) = 0.000437
C. through Mathematics Anxiety (0.165 * 0.100) = 0.016500
D. through Mathematics Anxiety and Mathematics Behaviour (0.0165 x –0.154 x –0.079) = 0.111201
E. through Mathematics Motivation (0.015 x –0.105) = - 0.001575
F. through Mathematics Motivation and Mathematics Anxiety (0.015 x –0.247 x 0.100) = -0.00037

G. through Mathematics Motivation and Mathematics Behaviour (0.015 x 0.165 x –0.079) = -0.0002

H. through Mathematics Motivation, Mathematics Anxiety, and Mathematics Behaviour (0.015 x –0.247 x -0.154 x –0.079) = -0.00045

Total effect is the sum of the direct effect and indirect effects:
Total effect = (0.015) + (0.000213 +0.000437 + 0.016500 + 0.111201 – 0.001575 –0.00037 - 0.0002 – 0.00045) = 0.140756

It is evident that among various paths, the path of "Gender-> Mathematics Motivation -> Trauncy" (-0.001575) is most effective in lowering the incidence of Truancy.

The total indirect effect of Gender (dummy coded) on Truancy is positive and quite low, and the direct effect of Gender on Truancy is positive and slightly larger. The total effect of Gender (dummy coded) on Truancy is: 0.140756, indicating that Gender (dummy coded) has a low positive effect on Truancy.

The collinearity diagnostics for the regressions indicate a low Variance Inflation Factor (VIF) (ranging from 1.038 and 1.15) and a moderate level of tolerance (ranging from 0.870 to 0.964).

Table 4: Regression coefficients*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.278	.010		127.209	.000		
	GENDER Gender (dummy coded)	.006	.014	.006	.455	.649	.964	1.038
	ANXMAT Mathematics Anxiety	.032	.007	.058	4.608	.000	.908	1.101
	ANCINSTM Instrumental Motivation for Mathematics (Anchored)	-.037	.008	-.064	-4.961	.000	.872	1.147
	SUBNORM Subjective Norms in Mathematics	-.045	.007	-.082	-6.369	.000	.870	1.150
	MATBEH Mathematics Behaviour	-.014	.007	-.026	-2.021	.043	.883	1.132

*a Dependent Variable: ST09Q01 Truancy - Skip whole school day

Discussion

The results of analysis were that Gender (dummy coded) has a low positive effect on Truancy; moreover, working through lowering students' Anxiety about Mathematics is most effective in lowering the Truancy incidence.

On the macro level, a number of conditions would impact pedagogical emphases and instructional methods for comparing mathematics performance, such as the different languages used in an assessment, as well as the social, economic, and cultural contexts of the countries (Romberg & Wilson, 1995; Schoenfeld, 1992; Silver & Cai, 2005; Watt, 2005; Wiggins, 1990).

From a microscopic viewpoint, it has to be mentioned that assessing students' mathematics performance or their educational performance poses various challenges, and the results can be affected by students' abilities, attitudes, and their social backgrounds, and even on how they might respond to the same set of tasks (Berenson & Carter, 1995; Charles, Lester, & O'Daffer, 1987; Cohen & Fowler, 1998; English, 1997; Reynolds, Livingston, & Willson, 2009).

The well planned PISA 2012 survey is focused on a real-life context to measure students' mathematical thought and action, including students' fundamental mathematical capabilities: communication, representation, devising strategies, mathematisation, reasoning and argument, using symbolic, formal and technical language and operations, and using mathematical tools (OECD, 2014a). The PISA 2012 Assessment and Analytical Framework offers a lens to investigate this research and to closely examine Canadian youths' mathematical performance and explore the conceptual model with two major orientations. By reviewing the proposed hypotheses of this analysis, one can see that a student has less mathematic anxiety; she or he would engage more with mathematic learning and there would be a decrease in the Truancy rate.

Conclusion

This study empirically evaluated the learning experience of Canadian youth in Mathematics, based on existing theoretical tenets, to explore a conceptual model that depicts two major orientations: one is internal aspects, which refers to how the students feel, and another is external aspects, referring to how the students behave. From the above analysis, educators might give certain attention to the major concern of how students' feel, which this research proposes using the term internal aspects to reflect; an example would be students' anxiousness regarding mathematics. One might suggest teachers apply formative practices or teaching approaches, for instance, encouraging students when they perform tasks during the classes, giving students feedback after the assessment, identifying students' strengths and weakness in mathematics to offer different methods, providing plenty of information to students becoming more active in mathematics, and assisting students individually to understand their needs and anxiety.

One limitation of this research is the scope of the research, such as the age of students, the country, the conceptual model, and the specific variables, internal and external aspects, that this research applies; another limitation is the time frame; for instance the research could follow the case for another three years or compare the last three years if the future conditions allowed, since PISA reports youth performance in Mathematics every three years and the major focus on mathematical literacy was in the PISA 2012 assessment.

The contribution of this study is that the results could support policy targets by establishing measurable goals for consideration and implementation, and assist in setting trajectories for reform; it will also inform all stakeholders such as educators, researchers, parents, governmental organizations, and policy makers regarding our understanding of individuals' academic and learning patterns, as the researcher contends.

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