Identifying the Predictors of Mathematics Anxiety, Confidence, and Performance in Canada: An Educational Data Mining Approach

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Conditional Grant Contract Number: 2022-0046

March 13, 2024

Abstract

The goal of this study was to identify important and actionable (i.e., can be acted upon) predictors of mathematics performance, mathematics anxiety, and confidence in mathematics among Canadian and Alberta students. The study followed an explanatory sequential mixed methods design, combining educational data mining with qualitative feedback from mathematics subject experts. In Phase 1, we surveyed mathematics subject experts from the Calgary Catholic School District (CCSD) regarding the importance of selected predictors from the *Trends in International Mathematics and Science Study* (TIMSS) 2019 assessment administered by the International Association for the Evaluation of Educational Achievement (IEA) and the *Programme for International Student Assessment* (PISA) 2018 assessment administered by the Organisation for Economic Co-operation and Development (ORCD) and then conducted educational data mining (EDM) analyses using the predictors that were rated highly by the experts (Phase 2). In Phase 3, we conducted a focus group with the mathematics experts to explore the actionability of important predictors in the models. Key actionable predictors for Grade 4 mathematics performance included class size, using longer tests for mathematics assessment, and school socioeconomic status (i.e., average education and income background of students' families). For mathematics anxiety, actionable predictors included disorderly behaviour in mathematics classes, class size, and student attendance. For confidence in mathematics, key actionable predictors included instructional clarity in mathematics lessons, disorderly behaviour in mathematics classes, and students feeling hungry at school. Actionable predictors for 15-year-old students' mathematics performance included lack of teaching staff, the frequency of consultation for school improvement, and implementing policy to improve students' reading. Results of the Phase 3 consultation were consolidated into a list of 18 recommendations. Overall, the findings from this study contribute to our broader understanding of the predictors that are most correlated with students' mathematics outcomes and highlight several opportunities for supporting students in mathematics.

Keywords: *mathematics performance, mathematics anxiety, confidence in mathematics, mixed methods, educational data mining, TIMSS, PISA.*

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Section 1: Introduction

Rationale for the Research

Over the last decade, Canadian students have demonstrated mixed performance in standardized assessments of mathematics achievement. For example, on the 2018 *Programme for International Student Assessment* (PISA) 2018, Canadian students performed well overall, although Canada's performance across time does not reflect improvements seen in other countries (Councils of Ministers of Education Canada, 2019). On the *Trends in International Mathematics and Science Study* (TIMSS) 2019 assessment, Canada stayed behind thirty other countries in the proportion of Grade 4 students that met the benchmark for advanced mathematics performance (Mullis et al., 2020). Results from Alberta students also exhibit a similar pattern. On the PISA 2018 assessment, Alberta's mathematics scores were on par with the national average; however, sixteen percent of students did not meet the threshold for basic mathematical skills needed for everyday life (Councils of Ministers of Education Canada, 2019). In the 2019 administration of TIMSS, Alberta's mathematics scores were significantly lower than the national average, and twelve percent of students did not meet the benchmark for basic mathematics proficiency (Councils of Ministers of Education Canada, 2021). Provincial achievement tests (PATs) and diploma examination results also show that Alberta students continue to struggle with mathematics (Alberta Government, 2019). For example, the percentage of students meeting the acceptable standard on the Grade 9 mathematics PAT has decreased by ten percent since the 2016/17 exam (Alberta Government, 2019). Overall, these findings highlight the need for improving mathematics achievement among Canadian and Alberta students.

Project Background

This project followed a mixed method approach that combined quantitative findings from educational data mining (EDM) and qualitative input from educational specialists to identify the critical predictors of mathematics-related outcomes based on PISA and TIMSS. EDM is a collection of analysis methods that extract insights from large-scale educational datasets (Depren et al., 2017). Using EDM methods allowed us to examine the effects of over a hundred predictors included in the databases of PISA 2018 and TIMSS 2019 and thereby obtain a deeper understanding of what is needed to improve mathematics-related outcomes in Alberta. It should be noted that predictive EDM models tend to put a great deal of emphasis on unmalleable student characteristics (e.g., age, gender, school location, and parental education) for the sake of improving prediction accuracy (Depren et al., 2017; El Aissaoui et al., 2020; Ramaswami & Bhaskaran, 2010). Therefore, such EDM models often fail to provide insights into more salient and actionable predictors that could contribute to the planning and decision-making processes of education stakeholders (e.g., teachers, school districts, and government agencies responsible for education). The term 'actionable variables' or 'predictors' refers to those factors that can be altered through targeted interventions, contrasting with the previously mentioned immutable characteristics. It's important to note that the terms 'variable' and 'predictor' are used interchangeably here, not only to add variety to the text but also to prevent monotony in the writing. For example, students' self-efficacy may be actionable from the implementation of student support programmes, while school locations cannot be changed. In this study, we followed a mixed methods design by integrating (1) theory-driven findings from previous studies in the literature, (2) data-driven findings from EDM analyses, and (3) expert evaluations regarding the *importance* and *actionability* of identified predictors. Our goal is to take a human-centred approach that explores both the predictive power of EDM models and the experiences of educational specialists for finding actionable insights into how to improve mathematics-related outcomes in Alberta.

Our study involved comprehensive EDM analyses of Alberta results in the PISA 2018 and TIMSS 2019 datasets and aligns with Research Priority #4. The study had two primary objectives: (1) to integrate theory, data-driven observations, and expert knowledge to produce models of mathematics performance, anxiety, and confidence among Alberta students, and (2) to use the models to generate actionable recommendations for mathematics educators, school districts, and the Ministry of Education. In this study, the term 'experts' specifically refers to mathematics teachers from the collaborating school district. These teachers, with their extensive teaching experience, are uniquely positioned to offer valuable insights. They can identify which predictive factors can be practically modified within the school environment. Their expertise bridges the gap between theoretical research and practical application in the educational setting. These recommendations represent empirically based opportunities that education stakeholders can use to enhance the quality and effectiveness of mathematics education in Alberta. Our study also aims to provide insights into the key drivers of mathematics performance among Alberta students. These insights can help us build a proactive approach to reducing and reversing the effects of pandemic-related learning loss in mathematics.

Another goal of our study is to produce recommendations for improving mathematics instruction in Alberta schools, guided by the mixed methods approach involving educational data mining and the practical perspective of subject matter experts. Therefore, we focus on malleable predictors (i.e., student characteristics that can be influenced by teachers, school staff, or policymakers) to provide insights and recommendations for policy decisions and mathematics instruction. Additionally, we aim to bridge the gap between theory and practice by focusing on changeable predictors pertaining to the mathematics behaviour of students. We intended to transform our findings into practical outcomes for various educational stakeholders, which is a significant element that most EDM studies have neglected in the literature. Focusing on malleable predictors will help us derive practical insights applicable at the provincial and school levels. Our school partner, CCSD, will benefit from this project by obtaining results directly related to their context. Other school districts can also benefit from this study by adjusting the recommendations to fit their population and practices. We will ensure that the results are available to all educators or researchers who are interested in improving mathematics-related outcomes (i.e., performance, anxiety, and confidence) based on the formulated recommendations.

Literature Review

Previous research shows that students' mathematics performance correlates with two mathematics-related outcomes: mathematics anxiety and their confidence in mathematics. Mathematics anxiety refers to feeling nervous or fearful when performing mathematics-related tasks (Ashcraft, 2002). Students who experience mathematics anxiety tend to avoid doing complex mathematics tasks (Choe et al., 2019) and are less likely to have a future career in Science, Technology, Engineering, and Mathematics (STEM) (Ahmed, 2018). Analogously, poor academic performance in mathematics is expected to trigger mathematics anxiety and avoidance among students (Aarnos & Perkkilä, 2012; Barroso et al., 2021; Chang & Beilock, 2016). Mathematics performance is also strongly related to students' confidence in handling mathematics tasks (Erickson

& Heit, 2015). This shows that the relationship between students' confidence in mathematics (also called mathematics self-efficacy) and mathematics performance is mutually reinforcing. While better performance in mathematics leads to greater confidence in mathematics (Ganley & Lubienski, 2016), students who have less confidence in mathematical abilities are at greater risk of underperforming in mathematics (Organisation for Economic Co-Operation and Development [OECD], 2013). Also, improving students' confidence in mathematics leads to lower levels of mathematics anxiety (O'Leary et al., 2017). Previous research shows that mathematics performance, anxiety, and confidence are associated with various cognitive and non-cognitive factors (Ruff & Boes, 2014). However, no previous study has explored these factors specifically among Alberta students. Our research insights into which elements should be targeted to improve mathematics-related outcomes in Alberta, could help identify new opportunities for improving the quality of mathematics instruction in the province.

Research Questions

As previously mentioned, the primary goal of this study is to identify key factors associated with mathematics performance, mathematics anxiety, and confidence in mathematics among Canadian students, with a special focus on Alberta students. Specifically, the study will address the following research questions:

1) What are the most important predictors of students' mathematics performance, mathematics anxiety, and confidence in mathematics?
2) Based on the identified predictors of students' mathematics performance, mathematics anxiety, and confidence in mathematics, what are the key actionable recommendations for mathematics teachers, school districts, and Alberta education to improve students' mathematics-related outcomes?

To answer the research questions above, we employed an *explanatory sequential mixed methods* design, incorporating both quantitative (i.e., educational data mining of the PISA 2018 and TIMSS 2019 datasets) and qualitative (i.e., gathering perspectives of educational specialists) elements in a sequential order (see Figure 1). An explanatory sequential design involves merging insights from qualitative and quantitative components that occur in succession (Creswell & Creswell, 2018). The rationale behind this study design is to form recommendations that account for both quantitative components from EDM results and qualitative components from educational specialists, which could be unattainable with the usage of any single research paradigm. Furthermore, using a mixed methods design enables us to address the tendency of EDM models to overemphasize fixed student characteristics described earlier. Based on the qualitative input from educational specialists, we decide on the *importance* and *actionability* of each identified predictor in terms of improving mathematics-related outcomes.

The project consisted of three phases. In *Phase 1*, we reviewed the full list of PISA 2018 and TIMSS 2019 variables to identify potential predictors of the mathematics-related outcomes (i.e., performance, anxiety, and confidence). Each database consists of hundreds of variables related to students, teachers, and schools collected through questionnaires and assessments; this study focused on relevant student-level and teacher-level variables only. After we reviewed the full variable list, we also reviewed previous studies that focused on mathematics-related outcomes and created a list of predictors that considered previous research findings. Next, we surveyed our research partners at CCSD to refine the predictor list based on their experiences and observations in elementary and high school classrooms. That is, we narrowed down the list of potential predictors based on the CCSD team's perspectives on the importance (i.e., how effectively each predictor can predict mathematics-related outcomes- of the identified predictors. Phase 1 produced a list of key predictors for each assessment (i.e., PISA 2018 and TIMSS 2019).

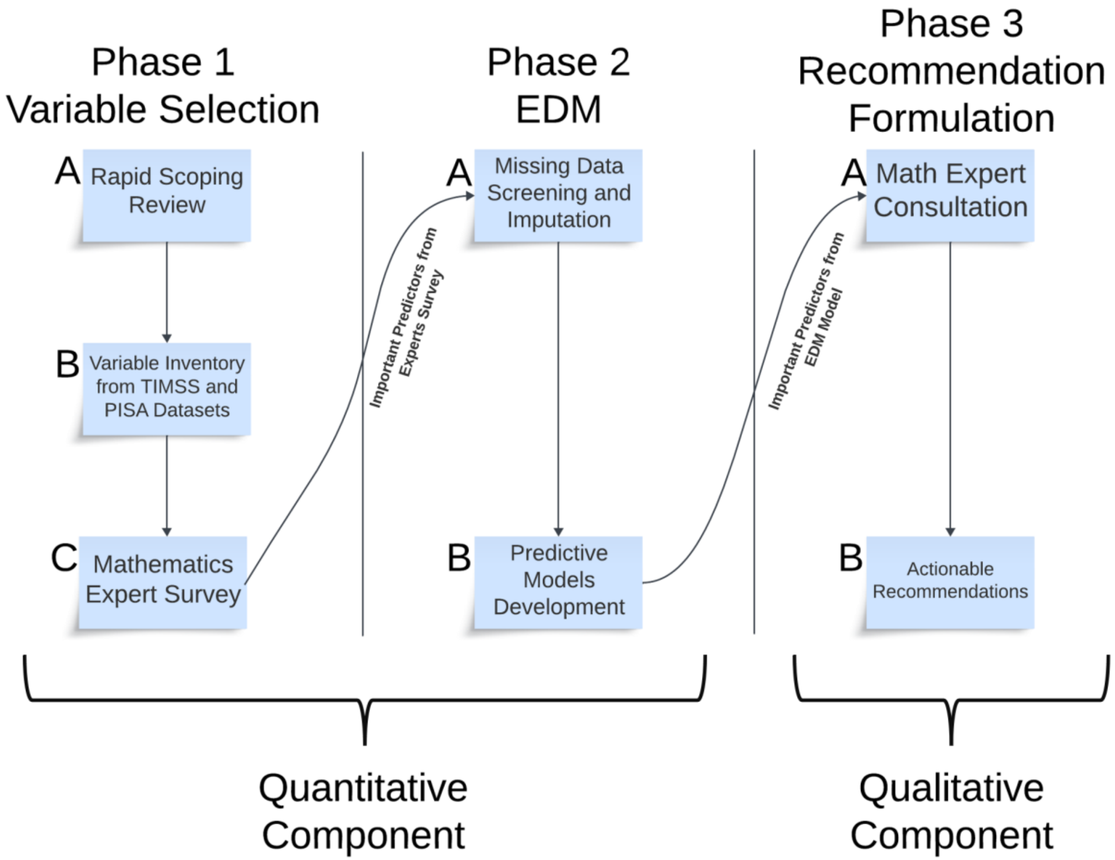
In *Phase 2*, we conducted a series of educational data mining analyses using the identified variables. First, we performed recursive feature elimination, a process that eliminates uninfluential predictors (RFE; Guyon et al., 2002), to remove weak predictors from the PISA and TIMSS databases using a programming package named *caret* (Kuhn, 2021) in the R software program (R Core Team, 2021). RFE begins by building a predictive model on the full set of predictors and computing an importance score for each predictor. Then, the least important predictor is iteratively removed, the model is re-built, and importance scores for the remaining predictors are re-computed until a desired number of predictors remains. In addition to RFE, we used a hybrid method combining feature selection and ensemble (Liu & Shi, 2021) to cross-validate the importance scores computed for the predictors. We performed these analyses on the entire Canadian and Alberta samples in the data set. Overall, these analyses yielded a shorter list of predictors for each mathematics-related outcome for all students across Canada and specifically for Alberta students. Then, we used the refined lists of predictors to build machine learning models for each mathematics-related outcome and estimate the models using the random forest algorithm (separately for the Canadian and Alberta samples) in the tidymodels package (Kuhn & Wickham, 2020) in R. The machine learning models allowed us to evaluate the performance of the selected predictors in predicting mathematics performance, anxiety, and confidence. Together, the first two phases produced quantitative findings regarding the key predictors of mathematics-related outcomes.

In *Phase 3*, we presented the results of the machine learning models to the CCSD educational specialist team to identify the most important and actionable predictors (up to 10 predictors for each mathematics-related outcome). The result was a list of recommendations for mathematics teachers, district- or school-level interventions to improve learning environments, and instructional strategies for mathematics teachers. The actionable recommendations will inform education stakeholders (e.g., teachers and learning teams at school districts) about existing interventions, school programs, and similar activities related to mathematics performance, anxiety, and confidence and highlight the areas for which new education reforms are needed. We will also focus on knowledge-mobilization activities to share our findings with various stakeholders during this phase.

Our sample includes Canadian students who participated in PISA 2018 and TIMSS 2019. A total of 22,653 15-year-old Canadian students participated in PISA, including 2,199 Alberta students. TIMSS data were collected from Grade 4 and Grade 8 students. In Canada, 13,653 students from five provinces, including Alberta, participated in Grade 4 TIMSS. Only the provinces of Ontario and Quebec participated in Grade 8 TIMSS. Therefore, our study targets 15-year-old Canadian secondary school students who participated in PISA 2018 and Grade 4 Canadian elementary school students who participated in TIMSS 2019. While the data was collected prior to the current period (2023), insights drawn from the study could point out the areas that need improvements and are exacerbated as time passes.

Figure 1

Design Diagram of the Study



Note. This diagram presents an *explanatory sequential mixed methods* design employed by this study. The research design incorporates both quantitative (i.e., educational data mining of the PISA 2018 and TIMSS 2019 datasets) and qualitative (i.e., gathering perspectives of educational specialists) elements.

Section 2: Practitioner Researcher Collaboration

Research Partnership Overview

Our ongoing research partnership with the Calgary Catholic School District (CCSD) represents a collaborative effort to advance mathematics education through a comprehensive project. The initial CCSD team, comprised of esteemed mathematics experts Helmut Kaiser, Kevin Deforge, Jocelynn Vryenhoek, and Shelley Gartner, played pivotal roles in the early stages of the project. As the project progressed, administrative shifts within CCSD necessitated changes in our team composition. Kevin Deforge, Jocelynn Vryenhoek, and Shelley Gartner transitioned back to teaching roles, leading to the inclusion of new members Kirk Linton, Lynn Leslie, Lydia Wong, and Jessie Zanutig. These additions further enriched our team with specialized expertise in mathematics education.

Our collaborative journey with CCSD stems from a prior Research Partnership Project conducted between 2019 and 2021 (Bulut et al., 2020; Deforge et al., 2022). During this period, we focused on developing the "Student Voice" survey, emphasizing non-cognitive skills such as student wellness, engagement, commitment to learning, and resilience. The success of this initiative laid the groundwork for a sustained partnership, and the ongoing collaboration between the research team and CCSD has evolved into a dynamic and enduring partnership. Thus, the genesis of the current project can be traced back to continued dialogue with Kevin Deforge, who played a crucial role in facilitating the collaboration with CCSD. In this project, CCSD team members have been actively engaged in multiple stages, thus contributing invaluable insights and expertise. Their substantial feedback on predictors of mathematics achievement, mathematics anxiety, and confidence in mathematics has proven instrumental. Leveraging a vast database of PISA and TIMSS exams, we have been able to identify and refine the most effective predictors to enhance mathematics education outcomes. This evolving partnership underscores our commitment to advancing the field of mathematics education through collaborative research, leveraging the collective expertise of both our team and the dedicated professionals at CCSD. Together, we aim to make lasting contributions to the understanding and improvement of mathematics education practices.

Celebrations

Throughout our collaborative project with the Calgary Catholic School District's (CCSD) mathematics experts, we have celebrated numerous milestones and achievements that reflect the strength of our partnership. One of the key highlights is our joint effort to identify the best predictors of mathematics achievement, mathematics anxiety, and confidence in mathematics. A noteworthy celebration came as we recognized the unique contribution of the CCSD team members. Their expertise and insights added a distinct Canadian perspective to our research. While these constructs had been studied by many researchers globally, the scarcity of information within the Canadian context presented a unique challenge and opportunity. Our collaboration allowed us to bridge this gap in the literature. Through extensive discussions, data sharing, and collaborative analysis sessions, we were able to view the field through their eyes, bringing a depth of understanding that enhanced the quality and relevance of our research.

The celebration extended to the development of a robust data analysis plan for our educational data mining analysis. The CCSD team's input significantly strengthened our approach, ensuring that our analysis was not only academically sound but also reflective of the intricacies of the Canadian education system. In recognizing these accomplishments, we organized joint sessions to acknowledge the contributions of each team member. A celebratory event provided an opportunity to express gratitude and appreciation for the shared commitment to excellence in research. This collaborative spirit was not only reflected in the outcomes but also in the strengthened bonds between our team and the CCSD experts. As a testament to our shared success, we plan to document these collaborative achievements in joint publications and presentations. Celebrating our journey together will not only enhance the quality of our research but also foster a sense of pride and accomplishment among all team members. This collaborative celebration serves as a reminder of the power of partnerships in advancing the understanding and improvement of mathematics education within the Canadian and provincial context.

Challenges

Our collaborative project with CCSD brought to light several challenges, each offering valuable insights into the dynamics of working together on a research initiative.

One significant challenge arose during the initial stages of the study, when we sought feedback from the CCSD team on variables within the PISA and TIMSS databases. The task of identifying important predictors proved more complex than anticipated. Recognizing the need for a more streamlined approach, we faced the challenge head-on by simplifying the task into steps and broadening our consultation process. Kevin Deforge, a key member of the CCSD team, suggested leveraging the collective expertise within CCSD schools by sharing the list of variables through an online survey with mathematics teachers and experts. This innovative approach yielded a wealth of valuable feedback, enabling us to refine our list of predictors effectively.

Another challenge emerged in the form of team member transitions within CCSD. Except for Helmut Kaiser, the composition of the CCSD team underwent substantial changes before the project's culmination. This necessitated reintroducing the project to the new team members, a process critical for their effective involvement in the final stages. The challenge highlighted the importance of effective communication and knowledge transfer within collaborative projects, ensuring that the evolving team dynamics did not hinder the project's continuity. To address this challenge, we organized dedicated sessions to familiarize the new team members with the project's objectives, methodologies, and findings up to that point. This step proved crucial in securing their commitment and ensuring their input in determining the actionability of the predictors identified through our predictive modelling analyses.

These challenges, though formidable, provided us with opportunities for growth and refinement. The iterative nature of our collaboration allowed us to adapt and evolve, reinforcing the resilience of our partnership. Ultimately, the challenges encountered in our collaboration with CCSD underscored the importance of flexibility, effective communication, and the willingness to explore innovative solutions as integral components of successful research partnerships.

Research Partnerships Program Cohort

Our team's participation in the Research Partnerships Program (RPP) Cohort 5, facilitated by the Research Branch in the Ministry of Education, Government of Alberta, has been a rewarding and enriching experience. The comprehensive support and structured events provided throughout the study significantly contributed to the success of our project. The journey commenced with an online onboarding meeting in June 2022, setting the tone for collaboration and establishing a robust foundation for our project. This initial interaction allowed us to familiarize ourselves with the expectations, resources, and fellow participants within the cohort.

One of the standout features of our experience was the Alberta Research Network (ARN) fall 2022 meeting, a pivotal event that provided a platform for knowledge exchange, networking, and the sharing of project progress. Engaging with other researchers in the cohort offered diverse perspectives and insights, fostering a collaborative spirit that transcended individual projects. The grant recipient presentations were instrumental in displaying the breadth and depth of research within the cohort. These presentations not only allowed us to highlight the unique aspects of our project but also provided a forum for constructive feedback and shared learning.

Throughout the cohort study, the Research Branch provided reporting templates for the interim and final reports, which streamlined the documentation process. The clarity and structure of these templates ensured a standardized approach to reporting, making it easier for our team to articulate the project's methodology, findings, and implications. One of the most noteworthy aspects of our experience was the streamlined process for projects involving secondary data analysis. The Research Branch's provision of clear instructions and continuous feedback created a supportive environment that allowed our team to navigate the complexities of secondary data analysis (e.g., large amount of information) with confidence. This streamlined approach proved instrumental in keeping our project on track, enabling us to meet our objectives without any delays.

In summary, our team's participation in RPP Cohort 5 has been marked by effective collaboration, valuable support, and structured events that enhanced the overall research experience. The simplified processes and comprehensive assistance provided by the Research Branch played a pivotal role in our project's success, allowing us to contribute meaningfully to the goals of the cohort and advance our understanding of education research.

Celebrations

One of the significant celebrations within the RPP Cohort 5 was the opportunity to display our ongoing efforts in educational data mining at the University of Alberta. Dr. Okan Bulut's strong advocacy for using large-scale assessments to inform instructional practices and education policies resonated well within the cohort. The showcase allowed our team to share the progress, methodologies, and potential impact of our study, fostering a sense of pride and recognition for our contributions.

The establishment of a diverse research team was a notable celebration. The inclusion of mathematics experts from the CCSD and ambitious graduate students passionate about employing EDM methods added a dynamic dimension to our project. This diversity brought varied perspectives and expertise to the table, enhancing the depth and richness of our research endeavours.

Our team expressed gratitude for the opportunity to delve into publicly available datasets from PISA and TIMSS. This access provided a unique chance to contribute to the enhancement of mathematics education not only in Alberta but also across Canada. The ability to leverage big data for insights and improvements in education underscored the meaningful impact of the research initiative.

In summary, the celebrations within Cohort 5 encompassed opportunities to highlight achievements, build a diverse and passionate research team, and utilize valuable datasets for impactful research. The absence of major challenges highlights the success of the cohort in fostering a conducive and collaborative research environment. The journey within Cohort 5 not only contributed to advancing our understanding of students' achievement, anxiety, and confidence in mathematics but also reinforced the positive impact of collective efforts in shaping the future of education research in Canada and Alberta.

Challenges

Interestingly, our team did not encounter significant challenges directly attributable to being part of Cohort 5. The structured and supportive environment provided by the Research Branch, coupled with effective communication, and streamlined processes, contributed to a positive and efficient research experience.

Lessons Learned

Our team's engagement in practitioner-researcher collaboration, particularly with the experts from the CCSD, has provided invaluable insights into the intricacies of educational research. Several key lessons have emerged from this collaborative endeavour:

- **Significance of Field Expertise**: The project underscored the importance of working together with practitioners and field experts to enhance the depth and impact of educational research. By involving mathematics experts from the CCSD team, we gained a nuanced understanding of the practical challenges within the educational landscape, surpassing what a traditional statistical analysis could offer.
- **Moving Beyond Statistical Analysis**: The collaboration challenged our approach to educational research. Instead of relying solely on statistical analyses, we engaged in a collaborative process with CCSD experts to identify important predictors of mathematics achievement, mathematics anxiety, and students' confidence in mathematics. This shift from a purely quantitative focus to a more qualitative, practitioner-driven exploration enriched our research process and outcomes.
- **Actionability at Various Levels**: One of the most crucial lessons stemmed from the CCSD team's contribution to identifying actionable predictors. Their insights went beyond mere statistical significance, delving into the practicality and relevance of identified predictors at different levels, teacher, school, and policymaker. This eye-opening perspective emphasized the need for research findings to translate into actionable strategies for those directly involved in education.
- **Bridging the Gap Between Research and Practice**: The collaboration served as a bridge between research and practice. By actively involving practitioners in the research process, we ensured that our findings were not confined to academic discussions but had direct relevance

to the challenges faced in real-world educational settings. This alignment between research and practice is crucial for the effective implementation of evidence-based strategies.

- **Mutual Learning and Knowledge Exchange**: The collaborative nature of the project facilitated a two-way exchange of knowledge. While our team contributed research methodologies and analytical expertise, the CCSD team provided contextual insights, practical wisdom, and a nuanced understanding of the educational context. This mutual learning process enriched the overall research experience.

Suggested Next Steps

We identified several potential next steps in practitioner-researcher collaboration. First, we plan to collaborate with the CCSD team to develop and implement actionable strategies based on the identified predictors. We can work together to integrate these strategies at the teacher, school, and policymaker levels to address challenges related to mathematics achievement, mathematics anxiety, and confidence in mathematics. Second, we will consider engaging in longitudinal studies to track the effectiveness of the implemented strategies over time. This can provide a comprehensive understanding of the sustained impact of interventions on student outcomes and educational practices. Third, we plan to organize professional development workshops for teachers based on our research findings. We plan to work closely with CCSD to design workshops that empower educators to apply evidence-based practices in their classrooms, fostering continuous improvement in mathematics education.

Our team has some suggestions for the Research Branch to enhance the effectiveness of the RPP initiative. First, Research Branch can provide additional resources and support mechanisms for fostering practitioner-researcher collaborations. This can include networking events to facilitate stronger connections between researchers and educational practitioners. Second, Research Branch can implement capacity-building programs aimed at enhancing the research skills of practitioners. This can empower more educators across Alberta to actively contribute to research initiatives, fostering a culture of ongoing collaboration and knowledge exchange. Finally, Research Branch may consider establishing mechanisms to recognize and celebrate successful practitioner-researcher collaborations.

This could include awards or displays to acknowledge the impact of collaborative research efforts in improving educational practices and outcomes.

Section 3: Research Design

Research Design

This study used an *explanatory sequential mixed method* design. In this design, the results from a quantitative analysis (Phase 1 and 2) were explored using qualitative methods (Phase 3) (Creswell & Creswell, 2018). The findings from both phases were combined to generate comprehensive insight on a given topic. In our study, we first conducted a survey of mathematics subject experts to identify which factors were most important for students' mathematics-related outcomes (Phase 1). Variables rated highly by experts on the survey were included in educational data mining analyses using two large-scale educational datasets (Phase 2). Finally, we conducted a focus group with the mathematics subject experts to gather their input regarding the actionability of the most important factors in the statistical models (Phase 3).

Research Questions

The goal of this study was to identify important and actionable predictors of mathematics-related outcomes among students in Canada and Alberta. More specifically, we aimed to answer the following research questions:

1) What are the most important predictors of a) mathematics performance, b) mathematics anxiety; and c) confidence in mathematics?
2) Based on the identified predictors of mathematics performance, mathematics anxiety, and confidence in mathematics, what are the key actionable recommendations for mathematics teachers, school districts, and Alberta education to improve students' mathematics-related outcomes?

Participants

Mathematics subject experts were recruited from the CCSD to identify important predictors of mathematics outcomes via an online survey. The experts were primarily CCSD mathematics consultants; however, the survey (Phase 1) was also shared by the CCSD consultants with other mathematics educators in the district. All participants were invited to complete the survey by email, which included a link to the four survey forms (i.e., 15-year-old mathematics performance, Grade 4 mathematics performance, Grade 4 mathematics anxiety, Grade 4 confidence in mathematics). In total, 27 respondents completed the survey on 15-year-old mathematics performance, 21 completed the survey on Grade 4 mathematics performance, 10 completed the survey on Grade 4 mathematics anxiety, and 10 completed the survey Grade 4 confidence in mathematics.

For the focus group consultation, an email invitation was distributed to the CCSD participants informing them about the purpose of the focus group and to invite them to participate. At the beginning of the meeting, all participants were notified that the meeting would be video recorded. In total, six mathematics experts participated in the focus group. The group included both elementary mathematics experts and secondary mathematics experts. It is important to note that the experts who participated in the survey (Phase 1) and focus groups (Phase 3) were mostly different due to the standard rotation of consultants back into classroom teaching roles.

Data Collection Sources and Instruments

Mathematics Expert Survey (Phase 1)

One of the project research assistants reviewed the full list of available variables in PISA 2018 and TIMSS 2019 and identified any that were potentially relevant to students' mathematics outcomes. This process was informed, in part, by a rapid scoping review (Phase 1a) of the research literature on mathematics anxiety and mathematics performance. For this review, the research assistant searched Google Scholar and the ERIC research database using "mathematics performance", "mathematics anxiety" and "mathematics confidence" as keywords. Twenty articles were identified as highly relevant to the targeted mathematics outcomes. The predictors named in these articles were summarised in tabular format and informed the selection of items from the PISA and TIMSS databases. The inventory of mathematics-related variables was validated by the other members of the project team (Phase 1b). Next, the variables were compiled into four survey forms (Phase 1c), addressing (1) 15-year-old mathematics performance, (2) Grade 4 mathematics performance, (3) Grade 4 mathematics anxiety, and (4) Grade 4 confidence in mathematics. Importantly, several individual items from TIMSS and PISA were combined into overall variables (or factors) to reduce the length of each form. The survey forms for Grade 4 mathematics performance, Grade 4 mathematics anxiety, and Grade 4 confidence in mathematics included 75 factors; the survey for 15-year-old mathematics performance included 46 items. Respondents rated the importance of each variable on a three-point scale from 1 = Low importance, 2 = Moderate importance, and 3 = High importance. The survey method allowed us to efficiently collect experts' insights across many factors.

Educational Data Mining (Phase 2)

Educational data mining analyses were performed using the PISA 2018 and TIMSS 2019 datasets. PISA is an international assessment of 15-year-old students' academic abilities in mathematics and reading. In PISA 2018, students completed an assessment of their academic abilities in reading and mathematics; students and school principals also completed a survey about their demographics, attitudes, and school-related experiences. The PISA dataset includes a variable that distinguishes students by Canadian province (i.e., Newfoundland and Labrador, Prince Edward Island, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Nova Scotia). As such, we included the data from Alberta students only (*n* = 2,190).

TIMSS is an international assessment of Grade 4 and Grade 8 students' academic abilities in mathematics and science. Students, parents, teachers, and school principals also completed surveys about their demographics, attitudes, and school experiences. In this study, the Grade 4 dataset was selected to also examine the mathematics outcomes at a younger Grade level (Note: PISA focuses on 15-year-old middle-school students). Province-level data is not available for TIMSS, so the dataset includes students from Alberta, Manitoba, Ontario, Quebec, and Newfoundland and Labrador (n = 17, 528).

Mathematics Expert Focus Group (Phase 3)

Focus group data was captured using four tables which displayed the 20 most important variables from each of the statistical models. Several student-level factors were shaded grey in the table to indicate to the focus group that they were considered non-actionable variables and should not be endorsed. The tables initially included columns to indicate actionability on a Yes/No scale; however, based on feedback from the focus group participants (i.e., CCSD team members), this scale was extended to include 'Some' actionability. Actionability was indicated separately for different stakeholder groups. Our initial list included three groups (i.e., teachers, school administrators, policymakers/government); however, this list was extended to include 'system administrators' again based on feedback from the focus group. For each model, the CCSD focus group was also asked which three predictors in the model they would most recommend acting on to improve students' mathematics outcomes.

Data Collection Procedures

Mathematics Expert Survey (Phase 1)

The survey was conducted in December 2022. Survey data was collected using Google Forms provided by the University of Alberta. Access to the data was password protected and only accessible to members of the project team. It is important to note that the collected data will be erased in December 2028 according to university policies on the storage, retention, and destruction of research data for 5 years.

Educational Data Mining (Phase 2)

The PISA 2018 (OECD, 2019) and TIMSS 2019 (IEA, 2021) public datasets were downloaded by the two research assistants (Ashley and Tarid) in May 2023. We used the R statistical software to merge the data and perform the data analyses. One particular package (i.e., *intsvy) was used to* (1) subset the Canadian data, (2) merge assessment data (e.g., mathematics ability estimates, reading ability estimates) with survey data (i.e., student survey, teacher survey, etc.), and (3) select the relevant variables from each dataset.

Mathematics Expert Focus Group (Phase 3)

The 90-minute focus group was conducted through the Zoom software, in November 2023. The first 15 minutes of the meeting was allocated to: (1) research team and consultant introductions, (2) project overview, and (3) describing the focus group task. The remainder of the meeting was used to discuss the utility and actionability for each predictor identified through EDM analyses. One of the research assistants shared the relevant table on the screen and both research assistants took notes and updated the tables in real time based on the discussion.

Data Analysis

Mathematics Expert Survey (Phase 1)

Survey data from the four Google Forms was analysed using a linked Google Sheet. For each factor (i.e., predictor of mathematics achievement, mathematics anxiety, or confidence in mathematics), we calculated the percentage of responses in each response category (i.e., Low Importance, Medium Importance, High Importance), and ordered the factors from highest to lowest based on the percentage of respondents indicating it was of 'High Importance'. Next, we examined the distribution of these percentages, and identified suitable cut points for inclusion in the educational data mining models. In the context of the mathematics performance of 15-year-olds (as measured by PISA), we have chosen to retain only those factors that were deemed of 'High Importance' by more than 50% of the respondents for our educational data mining analyses. This approach ensures that our analysis focuses on the most significant factors as identified by most of the respondents. A list of 16 factors ranked below these thresholds in the survey, but the research team thought these factors may still be of importance to the study. Thus, this list of factors was sent back to the expert group by email asking for additional input. Subsequentially, ten of these factors were rated as important and added to the statistical models in Phase 2.

Educational Data Mining (Phase 2)

Both PISA 2018 and TIMSS 2019 datasets were screened for missing data. In PISA, the highest missingness percentage among all variables is 18.4%. We opted not to exclude any of the PISA variables from our analysis due to its moderate missingness. In TIMSS, three variables from the teacher survey related to homework with missingness greater than 35% were removed (i.e., ATBM06CA: Corrects homework and gives feedback, ATBM06CB: Discusses homework in class, ATBM06CC: Checks that homework is completed). Five TIMSS items that asked teachers about their mathematics assessment strategies (ATBM07A: Observe students as they work, ATBM07B: Ask students questions in class, ATBM07C: Short written assignments, ATBM07D: Longer tests, ATBM07E: Long-term projects) were initially excluded from the survey but added later as potential factors in the statistical models. One variable from the survey (i.e., ATBG10B: Having a split Grade class) was omitted from the educational data mining models because closer inspection revealed that it may not clearly differentiate split and non-split classrooms. The missing values for all variables were imputed using the random forest algorithm in the mice package. We checked the quality of our filled-in data by comparing it with the original data. This helped us ensure that our process of filling in missing information did not significantly alter the overall data. For TIMSS, some variables related to mathematics topics being covered (e.g., comparing and drawing angles) were flagged as poor imputation quality. For PISA, the imputation quality was acceptable and therefore no variables were removed at this stage. Following imputation, we split all the data into two parts.

We used 70% of the data to help our system learn and understand the patterns (aka the training dataset). The remaining 30% was used to check how well our system could use what it learned to make accurate predictions (aka the testing dataset). This process helped us identify the most influential factors.

Next, we used a data-driven method (i.e., lasso regression with glmnet) to reduce the number of variables in each model. With the variables selected from lasso regression, we built four random forest statistical models that predicted Grade 4 mathematics performance, Grade 4 mathematics anxiety, Grade 4 confidence in mathematics, and 15-year-old mathematics performance. Random forest is an educational data mining that uses various variables (or predictors) to generate a prediction for an outcome (e.g., mathematics self-efficacy). Random forest also provides a numeric score for the importance of each of the predictors in generating that prediction. The outcome (or predicted) variable for the Grade 4 mathematics performance model was the first mathematics ability estimate (ASMMAT01). ASMMAT01 is a value generated for each student that is an estimate of their mathematics ability, based on their performance on the PISA test. For the mathematics anxiety outcome, we used a single item (i.e., "Math makes me nervous") re-coded from a 4-point Likert item from 1 = "Agree a lot" to 4 = "Disagree a lot", into two categories that represented having some mathematics anxiety or not. For the confidence in mathematics outcome, we used the TIMSS mathematics self-efficacy scale score (ASBGSCM). This scale score is generated from nine items from the student survey that ask about students' self-efficacy in mathematics (e.g., "My teacher tells me I'm good at math"). Random forest statistical models were built using the ranger package and tuned with tuneRanger. For mathematics performance and confidence in mathematics, the models were evaluated using the R^2 and mean squared error (MSE) indices. For mathematics anxiety, the model was evaluated using R^2, accuracy, and *F1* score.

Focus Group (Phase 3)

Focus group notes were qualitatively examined and reorganized to summarize specific expert recommendations for each stakeholder group (i.e., teachers, school admin, system admin, policy/government). Next, we sent the updated tables back to the consultant group for a member review, and completion of any cells that were missed during the focus group meeting. Finally, a project research assistant synthesised the tables into a final list of recommendations. These recommendations were reviewed for consensus by the other members of the research team.

Validity and Reliability

The initial inventory of PISA and TIMSS variables was validated through research team consensus (i.e., the two research assistants and research lead agreed that the listed factors could be reasonably related to students' mathematics outcomes). Similarly, factors were deemed 'important' in the mathematics expert survey when there was high consensus (i.e., > 50% rated 'High Importance'). The educational data mining analyses were performed using validated assessment data, including mathematics performance indices, and scale scores (e.g., TIMSS Mathematics Self-Efficacy). For the focus groups, we conducted member checks with the participant group to ensure that our synthesis and interpretation was accurate.

Section 4: Findings

Mathematics Expert Survey (Phase 1)

For 15-year-olds' mathematics performance, there were 15 factors with greater than 50% of the experts rating them 'High Importance'. Mathematics instruction time per week (80.8%), student-teacher ratio (77.8%), and negative teacher behaviours at the school (77.8%) were the highest rated factors. For Grade 4 students' mathematics performance, there were 27 factors with greater than 60% of experts' rating them 'High Importance'. Teachers' classroom challenges (100.0%), students' school attendance (95.2%), and class size (95.2%) were the highest rated factors. For Grade 4 students' mathematics anxiety, there were 37 factors with greater than 60% of experts' rating them 'High Importance'. Teachers' classroom challenges (100.0%) and class size (100%) were the highest rated factors. For Grade 4 students' confidence in mathematics, there were 32 factors with greater than 60% of experts' rating them 'High Importance'. Class size (100.0%) and instructional clarity in mathematics lessons (100.0%) were the highest rated factors. Summary tables for the survey are provided in Appendix D.

Educational Data Mining (Phase 2)

Lasso Regression

For Grade 4 mathematics performance, variable reduction procedure removed 16 variables from the dataset; the remaining 99 variables were included in the educational data mining model. For Grade 4 mathematics anxiety, lasso regression removed 86 variables; the remaining 64 were included in the education data mining model. For Grade 4 confidence in mathematics, lasso regression removed 45 variables; 94 remaining variables were included in the educational data mining model. For Grade 9 mathematics performance in PISA, lasso regression removed 18 variables; and 42 remaining variables were included in the educational data mining model.

Random Forest

For Grade 4 mathematics performance, the Random Forest model[1] explained 73.1% of the total variability in mathematics performance on the training set (R^2 = 0.731, MSE = 0.269) and 69.7%

[1] The following fine-tuning parameters were used: mtry = 36, min.node.size = 2, sample.fraction = 0.837.

on the test set (R^2 = 0.697, MSE = 0.304). The most important variable in the model was students' estimated ability in science (ASSSCI01); this variable is the science equivalent of the mathematics estimate described earlier) The next most important variables were three items from the mathematics self-efficacy scale (ASBM05B: Math is harder for me, ASBM05H: Math is harder for me than other subjects, ASBM05A: I usually do well in math), and a parental education index (ASDHEDUP).

For Grade 4 mathematics anxiety, the Random Forest model[2] had 83.4% accuracy on the training set (Accuracy = 0.834, F1 score = 0.699) and 78.8% accuracy on the test set (Accuracy = 0.788, F1 score = 0.616). The most important variables in the model were three items from the mathematics self-efficacy scale (ASBM05I: Math makes me confused, ASBM05H: Math is harder for me than other subjects, ASBM05C: I'm not good at math), followed by students' estimated ability in science (ASSSCI01), and another item from the self-efficacy scale (ASBM05B: Math is harder for me).

For Grade 4 confidence in mathematics, the Random Forest model[3] explained 61.9% of the total variability in confidence in mathematics on the training set (R^2 = 0.619, MSE = 0.382) and 55.1% of the total variability on the test set (R^2 = 0.551, MSE = 0.447). The most important variables in the model were two items from the enjoy mathematics scale (ASBM02I: Math is one of my favourite subjects, ASBM02A: I enjoy math), followed by students' estimated ability in mathematics (ASMMAT01), and two more items from the enjoy mathematics scale (ASBM02G: Like solving math problems, ASBM02H: I look forward to math).

For 15-year-old mathematics performance in PISA, the Random Forest model[4] explained 57.7% of the total variability in mathematics performance on the training set (R^2 = 0.577, MSE = 0.409) and 58.2% on the test set (R^2 = 0.582, MSE = 0.366). The most important variable in the model was students' estimated reading score (PVREAD), followed by students' resilience (ST188Q01HA), the indication of inadequate or poor-quality educational material (SC017Q06NA), students' ability

[2] The following fine-tuning parameters were used: mtry = 16, min.node.size = 2, sample.fraction = 0.873
[3] The following fine-tuning parameters were used: mtry = 36, min.node.size = 2, sample.fraction = 0.875
[4] The following fine-tuning parameters were used: mtry = 20, min.node.size = 5.

grouping strategy (SC042Q02TA), and students' growth mindset (ST184Q01HA). Summary tables for the educational data mining analyses are provided in Appendix E.

Mathematics Expert Focus Group (Phase 3)

Overall, mathematics experts indicated that most of the important factors identified in the statistical models were actionable for all stakeholder groups. Across factors, a common theme was that teachers can take individual- or classroom-level action, school and system administrators can support teachers, and governments can provide appropriate policy support and ensure sufficient resources for the education system. For Grade 4 confidence in mathematics, they identified four key factors for actioning including two aspects of instructional clarity in mathematics (i.e., students know what the mathematics teacher expects, mathematics teacher is easy to understand), having a mathematics class that is too disorderly to work, and students feeling hungry at school. For mathematics anxiety, experts identified four factors including two aspects of disorderly behaviour in mathematics (i.e., a mathematics teacher must tell students to follow the rules, too disorderly in mathematics class to work), class size, and students' school attendance. For Grade 4 mathematics performance, experts identified three factors including class size, using longer tests for mathematics assessment, and school socioeconomic status. For Grade 9 mathematics performance in PISA, experts identified shortage of teaching staff at school, the frequency of consultation for school improvement, and the implementation of policy for the improvement in students' reading as key factors for actioning.

Importantly, the mathematics experts also identified that some of the student-level factors in the model were actionable (i.e., liking mathematics, confidence in mathematics). They discussed how (1) modelling and promoting a growth mindset, and (2) providing high quality mathematics instruction may impact these student-level outcomes. Summary tables for the focus groups are provided in Appendix F.

Section 5: Discussion and Conclusion

Discussion of Findings

In this study, we examined the important and actionable predictors of students' mathematics-related outcomes in Alberta and Canada. Regarding mathematics performance, we found that the key factors are students' academic ability in other subjects such as English reading, as well as other student-level characteristics including confidence in mathematics for Grade 4 students, and resilience for 15-year-olds. The key actionable factors identified by experts were class size, using longer tests for mathematics assessment, and school socioeconomic status for Grade 4 students, and staff shortage at school, the frequency of consultation for school improvement, and the implementation of policy for the improvement in students' reading for 15-year-olds in Grade 9 students. Regarding mathematics anxiety, we found that the most important factors related to other dimensions of students' confidence in mathematics. Experts identified disorderly behaviour in mathematics class size (e.g., students interrupt the mathematics teacher, disruptive noise, students don't listen, etc.) and student attendance as key actionable factors. Finally, regarding confidence in mathematics, we found that the most important factors related to students' enjoyment of mathematics as well as their academic abilities in mathematics and science. The key actionable factors identified by experts related to instructional clarity, disorderly behaviour in mathematics, and student hunger. Notable, class size was a relatively important factor across all of the statistical models. A summary of key findings and recommendations is provided below in Table 1.

Table 1

Key Findings and Recommendations

Mathematics Performance (Grade 4 students)	

• Students' academic ability in science and confidence in mathematics were the most important factors in the Grade 4 Mathematics Performance model.
  ○ This suggests that even at earlier Grades, students can self-identify having difficulties in mathematics.
  ○	

• Class size, longer tests, and school socioeconomic status were identified as key factors for action by mathematics subject experts.	• **<u>Recommendation 1:</u>** Where possible, school and system administrators should allocate students and teachers to reduce class size.

<table>
<tr><td></td><td><u>Recommendations 2:</u> Government should ensure adequate educational funding to maintain and/or reduce class size.</td></tr>
<tr><td colspan="2">Confidence in Mathematics (Grade 4 students)</td></tr>
<tr><td>Students' enjoyment of mathematics and their academic ability in mathematics and science were the most important factors in the Confidence in Mathematics model.
Mathematics experts reported that teachers' own dislike of mathematics and their poor instructional clarity/ability influenced students' enjoyment of mathematics.</td><td><u>Recommendation 3:</u> Implement best-evidence mathematics instructional supports for teachers that target (1) teachers' attitudes towards mathematics and (2) teaching mathematics clearly.</td></tr>
<tr><td>Four key factors were identified for action by mathematics subject experts: (1) students' knowing what the mathematics teacher expects, (2) students' having a mathematics teacher that's easy to understand, (3) disorderly behaviour in the mathematics classroom, and (4) students' feeling hungry at school.</td><td><u>Recommendation 4:</u> Teachers should clearly outline expectations for students in mathematics classrooms.
<u>Recommendation 5:</u> Teachers should engage in ongoing development of their mathematics pedagogy and classroom management skills.
<u>Recommendation 6:</u> School administrators should actively supervise and support teachers in their schools (i.e., walkthroughs/observations of mathematics teaching, flag teachers for mathematics pedagogical support, support teachers' implementation of mathematics curriculum, behavioural support etc.)
<u>Recommendation 7:</u> System administrators should provide evidence-based mathematics pedagogy and behavioural supports to teachers at the system-level that especially target (1) setting clear expectations in mathematics and (2) teaching mathematics clearly.
<u>Recommendation 8:</u> Government should set clear expectations within the mathematics curriculum.
<u>Recommendation 9:</u> Government should enact policies that help address classroom complexity.
<u>Recommendation 10:</u> School administrators, system administrators and government should advocate for and implement school food programs.</td></tr>
</table>

Mathematics Anxiety (Grade 4 students)	
• Students' confidence in mathematics and their academic abilities in science were the most important factors in the Mathematics Anxiety model. ○ Mathematics experts reported that teachers' own mathematics anxiety influences students' mathematics anxiety and confidence in mathematics.	• **Recommendation 11:** Teachers and school administrators should promote and model a growth mindset and use scaffolding to support students' developing mathematics skills.
• Disorderly behaviour in mathematics, class size, and student attendance were identified as key factors for action by mathematics subject experts. ○ Mathematics experts explained that actionability on absenteeism depends strongly on the *reason(s)* for student absences.	• **Recommendation 12:** Teachers should promote student attendance among students and parents. • **Recommendation 13:** School administrators should develop and enforce school-level policies for student attendance. • **Recommendation 14:** Governments should set appropriate legislative policies for minimum attendance and revisit them at regular intervals.
Mathematics Performance (15-year-olds)	
• Students' estimated performance in their reading ability was the most important factors in the mathematics performance model.	• **Recommendation 15:** There is a need for literacy intervention for students at risk. Outside agencies can also support students in this regard to reduce teachers' workload. Topics that can be covered are tiers of words, and subject-specific vocabulary.
• Three key factors were identified for actions by mathematics subject experts: (1) staff shortage at school, (2) the frequency of consultation for school improvement, and (3) the implementation of policy for the improvement in students' reading.	• **Recommendation 16:** Staff shortage can be supported by allocations of educational assistants by the education system and the government. This issue is related to the availability of funding. Teachers can advocate for the mitigation of this problem. • **Recommendation 17:** Teachers, school, and system administrators have to be receptive to the fact that Teachers can also request support from the consultants as well. • **Recommendation 18:** The implementation of schools' policy for students' improvement in reading is internally managed at the school-level. A detailed examination of each school policy is required to implement appropriate measures for addressing this variable.

Potential Scholarly and/or Education System Benefits

The results of this study can impact students and teachers by informing mathematics instruction and supportive interventions for Canadian and Alberta students. More specifically, educational stakeholders (i.e., teachers, school administrators, system administrators, and government) can review the 18 recommendations and consider which are actionable. For researchers, the study provides empirical insight into the important factors that relate to students' mathematics performance, anxiety, and confidence in mathematics. It also provides a methodological example of how modern statistical methods can be integrated with qualitative expert input.

Implications for Practice

A critical implication of this study is that high-quality mathematics instruction is supported throughout all levels of the educational system. Focussing on issues such as instructional clarity in mathematics, disorderly classroom behaviour, student attendance, student hunger, and class size may help to improve students' mathematics outcomes.

Recommendations for Future Research

TIMSS 2023 and PISA 2022 datasets will soon be available. We recommend that future studies replicate these analyses using these datasets to determine how various factors' importance may have shifted, especially since the COVID-19 pandemic. In addition, experts discussed the potential for teachers' own dislike or anxiety of mathematics can be transferred to students. Future studies should empirically examine this relationship to determine how it may also impact students' mathematics outcomes.

Conclusion

This explanatory sequential mixed methods study leveraged both modern quantitative methods using datasets from PISA and TIMSS and subject matter experts to identify important and actionable factors related to Canadian and Alberta students' mathematics outcomes. Based on the findings from this research, we can present to teachers, school administrators, and policy makers/government with 18 recommendations that are actionable to help support Canadian and Alberta students in mathematics.

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Appendix A: Final Budget

Budget Area/Items	Itemized Costs	Allocation of Funds			Actual Expenditure to Date
		RPP Funds	In-Kind	Matching	
Personnel					
• Research assistant (number of hours, rate/hour)	$13,500	$11,500		$2,000	$10,348
• School staff additional hrs (approx. 8hr/monthx9)	$9,000		$9,000		$9,000
• Salary costs for Dr. Bulut and other administrative personnel involved in the grant activities	$45,375		$45,375		$45,375
Supplies and Materials					
• Research equipment and technology support			$1,000		$1,000
• Research services at the U of A			$5000		$5,000
Knowledge Mobilization • Conferences fees (TBD) • Accommodations (TBD) • Transportation (TBD)	$3,300	$2,100 (Submission to the 2024 Canadian Society for the Study of Education conference in Montreal)		$1,200	$0
Indirect Costs of Research (up to 10% of total grant funds)	$1,360	$1,360			834.77
TOTAL	**72,535**	**14,960**	**$60,375**	**$3,200**	**$71,557.77**

Appendix B: Research Project Timeline

October 2022	Rapid scoping review to identify factors associated with student math outcomes
November 2022	Inventory of math-related factors in PISA 2018 and TIMSS 2019
December 2022	Math expert survey (Phase 1)
May – August 2023	PISA 2018 and TIMSS 2019 data pre-processing
September 2023	Educational data mining analyses (Phase 2)
October 2023	Submission to the 2024 Canadian Society for the Study of Education conference in Montreal
November 2023	Focus Group Consultation (Phase 3)
December 2023	Submission of draft final report to Alberta Education
February 2024	Submission of final report to Alberta Education

Appendix C: Knowledge Mobilization Plan

We plan to share the results of this study with both the scholarly and school communities through conference presentations, infographics, and a journal publication. To date, we have used the following venues to share our work:

Wongvorachan, T., Clelland A., Gorgun G., Bulut, O. (2022). Identifying the predictors of mathematics anxiety and performance in Canada: An educational data mining approach. *Alberta Academic Review, 5*(1), 2-2. https://doi.org/10.29173/aar134

Wongvorachan, T., Clelland, A., Gorgun, G., Bulut, O. (2022, April). *Identifying the predictors of mathematics anxiety and performance in Canada: An educational data mining Approach* [Conference Session]. Poster presented at the 14th Annual Graduate Student Research Showcase: Exploring Horizons, University of Alberta, Edmonton, AB, Canada.

Bulut, O., Clelland, A., & Wongvorachan, T. (2024, June). Identifying the predictors of mathematics performance and math anxiety in Canada: An educational data mining approach. Paper submitted to the annual conference of the Canadian Centre of Science and Education (CCSE), Montréal, QC.

In addition to the scholarly communities summarized above, we also aim to share our findings with as many teachers, school principals, and educators as possible and account for their perspectives on applying recommendations at the classroom, school, and district levels. Therefore, we will complete the following knowledge and mobilization activities:

1. We will prepare policy briefs and share them with CCSD, other school districts in Edmonton and Calgary, and Alberta Education. Policy briefs will allow us to synthesize our research findings into plain language with clear links to policy initiatives.
2. We plan to present the findings of our study at the Greater Edmonton Teachers' Convention in 2024. We aim to share paper copies of our policy briefs with teachers participating at the convention.
3. We plan to attend the uLead conference–the premier School Leadership conference in Alberta–in April 2024.
4. We will submit a short article along with an infographic summarizing our findings to the Alberta Teachers' Association's ATA Magazine—distributed to all teachers and school administrators across Alberta.
5. We will submit a proposal (for a poster or paper presentation) for the annual meeting of the National Council on Measurement in Education (NCME). Generally, the NCME submission portal opens in August. So, we will submit our proposal in August 2024 and present our work (subject to acceptance) in April 2025.

6. We will prepare a manuscript and submit it to a high-quality, peer-reviewed journal focusing on mathematics education. We will seek open-access options (e.g., U of A's Education and Research Archive) for the resulting publication so that our publication becomes publicly available.

Appendix D: Math Expert Survey Results

Gr 4 Math Performance (n = 21)	
Factor	*% High Importance*
[Teachers' classroom challenges (e.g., too many students in the class, need more prep time, too much pressure from parents, etc.)]	100.00%
[Students' school attendance]	95.20%
[Class size]	95.20%
[Students' desire to do well in school (teacher reported)]	90.50%
[Teachers' ability to inspire students (principal reported)]	85.70%
[Students apply what they've learned to new problem situations on their own]	85.70%
[Instructional clarity in math lessons]	81.00%
[Student practice math procedures on their own]	81.00%
[Work problems together as a class with guidance from teacher]	81.00%
[Students feeling hungry at school]	76.20%
[Students' sense of belonging at school]	76.20%
[Students' math self-efficacy]	76.20%
[Shortage of resources for students with disabilities]	76.20%
[Students' enjoyment of learning math]	76.20%
[Students listen to the teacher explain how to solve math problems]	76.20%
[Math instruction time per week (teacher reported)]	71.40%
[Negative student behaviours at school level (e.g., arriving late, classroom disturbances, cheating, theft, etc.)]	71.40%
[Students listen to the teacher explain new math content]	71.40%
[Split/blended grade class]	70.00%
[Teachers' job satisfaction]	66.70%
[Overall teaching strategies (e.g., relate lessons to students' lives, bring interesting materials, link new content to prior knowledge, etc.)]	66.70%
[Math topics covered (i.e., before this year, during this year, not introduced)]	66.70%
[Disorderly behaviour during math lessons]	66.70%
[Classroom teaching limited by students not ready for instruction]	66.70%
[Shortage of instructional materials]	66.70%
[Shortage of concrete objects (i.e., manipulatives)]	66.70%
[Shortage of supplies]	61.90%
[Teacher's success in implementing curriculum (principal reported)]	57.10%
[Shortage of instructional space]	57.10%
[Negative teacher behaviours at school level (e.g., arriving late or leaving early, absenteeism)]	57.10%
[Shortage of computer software/apps for math instruction]	52.40%
[Teachers understanding of school's curricular goals (principal reported)]	52.40%
[Shortage of library resources for math instruction]	52.40%
[Frequency that students work math problems independently during math class]	52.40%
[Students work in mixed ability groups]	47.60%
[Students' experiences with being bullied]	47.60%
[Collaboration between school leadership (including master teachers) and teachers to plan instruction]	47.60%
[Students having access to digital learning resources (e.g., books, videos, etc.)]	47.60%
[Students memorize rules, procedures, and facts]	47.60%
[Teachers' expectations for academic achievement (principal reported)]	42.90%
[Teachers' professional development in math (last 2 years)]	42.90%
[Students had math tutoring or extra lessons in the last 12 months (parent reported)]	42.90%
[Students' # months math tutoring or extra lessons in the last 12 months (parent reported)]	42.90%
[Teachers' self-reported professional development needs in math]	42.90%

Appendix D: Math Expert Survey Results

Gr 4 Math Performance (n = 21)	
Factor	*% High Importance*
[Students work in same ability groups]	42.90%
[Teachers' perceptions about school being safe and orderly (Safe and orderly school)]	42.90%
[Shortage of computer technology]	38.10%
[Teachers' homework marking or follow-up behaviour]	33.30%
[Number of instructional minutes per day]	33.30%
[Number of instructional days per week]	33.30%
[Students' ability to reach school's academic standards (teacher reported)]	28.60%
[Shortage of technologically competent staff]	28.60%
[Shortage of teachers with math specialization]	28.60%
[Shortage of heating/cooling/lighting]	28.60%
[Number of computers at the school for students]	28.60%
[Whether the school has a library]	25.00%
[Teachers # hours spent in formal professional development for math (previous 2 years)]	23.80%
[Shortage of calculators]	23.80%
[Computers/tablets available during math lessons]	23.80%
[Teacher years' experience]	19.00%
[Students' respect for classmates who excel academically (teacher reported)]	19.00%
[Shortage of audiovisual resources]	19.00%
[Shortage of school buildings and grounds]	19.00%
[Number of homework minutes assigned]	19.00%
[Whether the school has a learning management system]	19.00%
[Frequency using computer/tablet for math schoolwork (student reported)]	19.00%
[Frequency that teacher assigns math homework]	19.00%
[Students allowed to use calculators]	14.30%
[Total school enrolment (# students)]	14.30%
[Number of instructional days]	14.30%
[Teacher's post-secondary specialization was math]	14.30%
[School principal's years' experience]	9.50%
[Number of years that principal has been at current school]	9.50%
[Teacher highest level of education]	4.80%
[Teacher's post-secondary major was math]	4.80%

Appendix D: Math Expert Survey Results

Gr 4 Math Anxiety (n = 10)	
Factor	*% High Importance*
[Teachers' classroom challenges (e.g., too many students in the class, need more prep time, too much pressure from parents, etc.)]	100.00%
[Class size]	100.00%
[Students' school attendance]	90.00%
[Students feeling hungry at school]	90.00%
[Students' desire to do well in school (teacher reported)]	90.00%
[Math topics covered (i.e., before this year, during this year, not introduced)]	90.00%
[Students listen to the teacher explain how to solve math problems]	90.00%
[Shortage of resources for students with disabilities]	90.00%
[Students' sense of belonging at school]	80.00%
[Students listen to the teacher explain new math content]	80.00%
[Students' experiences with being bullied]	80.00%
[Students' enjoyment of learning math]	80.00%
[Students' math self-efficacy]	80.00%
[Negative teacher behaviours at school level (e.g., arriving late or leaving early, absenteeism)]	80.00%
[Shortage of supplies]	80.00%
[Overall teaching strategies (e.g., relate lessons to students' lives, bring interesting materials, link new content to prior knowledge, etc.)]	70.00%
[Instructional clarity in math lessons]	70.00%
[Frequency that students work math problems independently during math class]	70.00%
[Students apply what they've learned to new problem situations on their own]	70.00%
[Shortage of instructional space]	70.00%
[Disorderly behaviour during math lessons]	70.00%
[Negative student behaviours at school level (e.g., arriving late, classroom disturbances, cheating, theft, etc.)]	70.00%
[Classroom teaching limited by students not ready for instruction]	70.00%
[Shortage of instructional materials]	70.00%
[Shortage of concrete objects (i.e., manipulatives)]	70.00%
[Teachers' ability to inspire students (principal reported)]	60.00%
[Teachers' self-reported professional development needs in math]	60.00%
[Work problems together as a class with guidance from teacher]	60.00%
[Teachers' job satisfaction]	60.00%
[Math instruction time per week (teacher reported)]	60.00%
[Teachers' homework marking or follow-up behaviour]	60.00%
[Students memorize rules, procedures, and facts]	60.00%
[Students work in mixed ability groups]	60.00%
[Students' ability to reach school's academic standards (teacher reported)]	60.00%
[Students' respect for classmates who excel academically (teacher reported)]	60.00%
[Student practice math procedures on their own]	60.00%
[Shortage of computer software/apps for math instruction]	60.00%
[Teachers' expectations for academic achievement (principal reported)]	50.00%
[Teacher years' experience]	50.00%
[Split/blended grade class]	50.00%

Gr 4 Math Anxiety (n = 10)	
Factor	*% High Importance*
[Frequency that teacher assigns math homework]	50.00%
[Number of homework minutes assigned]	50.00%

Appendix D: Math Expert Survey Results

Gr 4 Math Anxiety (n = 10)	
Factor	*% High Importance*
[Students work in same ability groups]	50.00%
[Shortage of computer technology]	50.00%
[Total school enrolment (# students)]	50.00%
[Students had math tutoring or extra lessons in the last 12 months (parent reported)]	50.00%
[Number of computers at the school for students]	44.40%
[Teachers' success in implementing curriculum (principal reported)]	40.00%
[Teachers' professional development in math (last 2 years)]	40.00%
[Shortage of audiovisual resources]	40.00%
[# months math tutoring or extra lessons in the last 12 months (parent reported)]	40.00%
[Teachers' perceptions about school being safe and orderly (Safe and orderly school)]	40.00%
[Collaboration between school leadership (including master teachers) and teachers to plan instruction]	40.00%
[Shortage of technologically competent staff]	40.00%
[Students allowed to use calculators]	30.00%
[Teachers understanding of school's curricular goals (principal reported)]	30.00%
[Frequency using computer/tablet for math schoolwork (student reported)]	30.00%
[Computers/tablets available during math lessons]	30.00%
[Number of instructional minutes per day]	30.00%
[Students having access to digital learning resources (e.g., books, videos, etc.)]	30.00%
[Number of instructional days per week]	30.00%
[Shortage of school buildings and grounds]	30.00%
[Shortage of heating/cooling/lighting]	30.00%
[Number of years that principal has been at current school]	30.00%
[Shortage of library resources for math instruction]	30.00%
[Teachers' # hours spent in formal professional development for math (previous 2 years)]	20.00%
[Whether the school has a learning management system]	20.00%
[Shortage of teachers with math specialization]	20.00%
[Number of instructional days]	20.00%
[Whether the school has a library]	20.00%
[Shortage of calculators]	20.00%
[School principal's years' experience]	20.00%
[Teacher highest level of education]	10.00%
[Teacher's post-secondary major was math]	10.00%
[Teacher's post-secondary specialization was math]	10.00%

Appendix D: Math Expert Survey Results

Gr 4 Confidence in Math (n = 10)	
Factor	*% High Importance*
[Class size]	100.00%
[Instructional clarity in math lessons]	100.00%
[Students' school attendance]	90.00%
[Students apply what they've learned to new problem situations on their own]	90.00%
[Teachers' classroom challenges (e.g., too many students in the class, need more prep time, too much pressure from parents, etc.)]	90.00%
[Students' desire to do well in school (teacher reported)]	80.00%
[Students' enjoyment of learning math]	80.00%
[Students listen to the teacher explain new math content]	80.00%
[Classroom teaching limited by students not ready for instruction]	80.00%
[Students' experiences with being bullied]	80.00%
[Students' sense of belonging at school]	80.00%
[Teachers' ability to inspire students (principal reported)]	80.00%
[Split/blended grade class]	80.00%
[Math topics covered (i.e., before this year, during this year, not introduced)]	80.00%
[Negative student behaviours at school level (e.g., arriving late, classroom disturbances, cheating, theft, etc.)]	80.00%
[Negative teacher behaviours at school level (e.g., arriving late or leaving early, absenteeism)]	80.00%
[Teachers' expectations for academic achievement (principal reported)]	80.00%
[Shortage of instructional materials]	80.00%
[Students listen to the teacher explain how to solve math problems]	77.80%
[Student practice math procedures on their own]	70.00%
[Overall teaching strategies (e.g., relate lessons to students' lives, bring interesting materials, link new content to prior knowledge, etc.)]	70.00%
[Math instruction time per week (teacher reported)]	70.00%
[Students memorize rules, procedures, and facts]	70.00%
[Students work in same ability groups]	70.00%
[Students feeling hungry at school]	70.00%
[Teachers' job satisfaction]	70.00%
[Shortage of supplies]	70.00%
[Work problems together as a class with guidance from teacher]	60.00%
[Disorderly behaviour during math lessons]	60.00%
[Frequency that students work math problems independently during math class]	60.00%
[Teachers' success in implementing curriculum (principal reported)]	60.00%
[Students work in mixed ability groups]	60.00%
[Number of homework minutes assigned]	55.60%
[Students had math tutoring or extra lessons in the last 12 months (parent reported)]	50.00%
[Students' respect for classmates who excel academically (teacher reported)]	50.00%
[Students # months math tutoring or extra lessons in the last 12 months (parent reported)]	50.00%

Gr 4 Confidence in Math (n = 10)	
Factor	*% High Importance*
[Shortage of resources for students with disabilities]	50.00%
[Shortage of concrete objects (i.e., manipulatives)]	50.00%
[Shortage of instructional space]	50.00%
[Teachers' homework marking or follow-up behaviour]	44.40%
[Total school enrolment (# students)]	40.00%

Appendix D: Math Expert Survey Results

Gr 4 Confidence in Math (n = 10)	
Factor	*% High Importance*
[Number of computers at the school for students]	40.00%
[Shortage of computer technology]	40.00%
[Frequency that teacher assigns math homework]	33.30%
[Teachers' self-reported professional development needs in math]	33.30%
[Teacher years' experience]	30.00%
[Students' ability to reach school's academic standards (teacher reported)]	30.00%
[Teachers' perceptions about school being safe and orderly (Safe and orderly school)]	30.00%
[Teachers understanding of school's curricular goals (principal reported)]	30.00%
[Students having access to digital learning resources (e.g., books, videos, etc.)]	30.00%
[Shortage of computer software/apps for math instruction]	30.00%
[Shortage of calculators]	30.00%
[Number of years that principal has been at current school]	30.00%
[Shortage of teachers with math specialization]	30.00%
[School principal's years' experience]	30.00%
[Frequency using computer/tablet for math schoolwork (student reported)]	22.20%
[Computers/tablets available during math lessons]	22.20%
[Students allowed to use calculators]	20.00%
[Number of instructional minutes per day]	20.00%
[Shortage of library resources for math instruction]	20.00%
[Number of instructional days]	20.00%
[Number of instructional days per week]	20.00%
[Whether the school has a library]	20.00%
[Shortage of audiovisual resources]	20.00%
[Teacher highest level of education]	20.00%
[Shortage of heating/cooling/lighting]	20.00%
[Shortage of school buildings and grounds]	20.00%
[Teachers # hours spent in formal professional development for math (previous 2 years)]	10.00%
[Teachers' professional development in math (last 2 years)]	10.00%
[Collaboration between school leadership (including master teachers) and teachers to plan instruction]	10.00%
[Whether the school has a learning management system]	10.00%
[Shortage of technologically competent staff]	10.00%
[Teacher's post-secondary major was math]	0.00%
[Teacher's post-secondary specialization was math]	0.00%

Appendix D: Math Expert Survey Results

15-yr old Math Performance (n = 27)	
Factor	*% High Importance*
[Math instructional time per week (reported by students)]	80.80%
[Student:teacher ratio]	77.80%
[Negative teacher behaviours at school level (e.g., not meeting individual students' needs, resisting change, not being well prepared for classes, etc.)]	77.80%
[Negative student behaviours at school level (e.g., truancy, alcohol and drug use, students not being attentive, etc.)]	74.10%
[Students' skipping behaviour: full day]	72.00%
[Shortage of staff]	70.40%
[Students' motivation to master tasks]	66.70%
[Extent that students value school in general]	63.00%
[Lacking educational materials (e.g., textbooks, IT equipment, library materials)]	59.30%
[Students' fixed or growth mindset]	59.30%
[Students are grouped into **different ability classrooms**]	55.60%
[Students' self-efficacy in dealing with challenges]	55.60%
[Percentage of the schools' teachers with Bachelor's degrees]	55.60%
[Inadequate or poor-quality educational materials (e.g., textbooks, IT equipment, library materials)]	51.90%
[Percentage of the schools' teachers certified by province]	51.90%
[Students' desired educational attainment (i.e., highest level they **want** to complete)]	48.10%
[Students' skipping behaviour: some classes]	48.10%
[Students' learning goals (e.g., to learn as much as possible, master the material, etc.)]	48.10%
[Lacking physical infrastructure (e.g., building/grounds, heating/cooling systems, lighting, etc.)]	42.30%
[Inadequate or poor-quality physical infrastructure (e.g., building/grounds, heating/cooling systems, lighting, etc.)]	40.70%
[Students' educational expectations (i.e., highest level they **expect** to complete)]	40.70%
[School staff help students with their homework]	40.70%
[Students' general fear of failure]	40.70%
[Schools' rationale and use(s) for assessment]	37.00%
[Students' arriving late for school]	33.30%
[Students' experiences with being bullied]	25.90%
[Students' competitiveness]	25.90%
[Availability of career guidance for students]	25.90%
[School has a homework room]	24.00%
[Students' sense of belonging at school]	22.20%
[Schools' quality assurance activities (e.g., evaluations, systematic recording of school data, seeking written feedback from students on instruction, etc.)]	22.20%
[School has a peer tutoring program]	15.40%

15-yr old Math Performance (n = 27)	
Factor	*% High Importance*
[Students' tendency towards positive emotions]	14.80%
[Schools' capacity to use digital devices for teaching and learning]	14.80%
[Percentage of the schools' teachers that have completed professional development in the last 3 months]	14.80%
[Whether students have previously repeated a grade]	12.00%
[Whether students have been in French Immersion]	11.50%
[Number of data projectors]	11.50%
[School achievement data is used for accountability (e.g., data reported publicly, tracked over time by administrative authority, etc.)]	11.10%
[Availability of computers at school]	11.10%
[Total school enrolment (# students)]	7.40%

Appendix D: Math Expert Survey Results

15-yr old Math Performance (n = 27)	
Factor	*% High Importance*
[Type of job students expect to have at 30 years old]	3.80%
[Students are grouped by ability **within their class**]	3.70%
[Number of interactive whiteboards]	3.70%
[Percentage of the schools' teachers with Master's degrees]	3.70%
[Percentage of the schools' teachers with PhDs]	0.00%

Appendix E: Educational Data Mining Results

Math Performance (Grade 4)			
	Variable	Description	Value
1	ASSSCI01	Science plausible value (PV1)	1806.10
2	ASBM05B	**Math self-efficacy:** Math is harder for me*	201.21
3	ASBM05H	**Math self-efficacy:** Math is harder for me than other subjects*	122.57
4	ASBM05A	**Math self-efficacy:** Usually do well in math	79.74
5	ASDHEDUP	Parental education	66.51
6	ASBM05C	**Math self-efficacy:** I'm not good at math	68.11
7	ASBM05I	**Math self-efficacy:** Math makes me confused	57.10
8	ATBG10A	Class size	44.48
9	ATBM05BE	Math topics covered: Comparing and drawing angles	41.48
10	ATBM01	Math instruction time per week (teacher reported)	37.03
11	ATBM05BD	Math topics covered: Parallel and perpendicular lines	32.19
12	ASBM02I	**Enjoy math:** Math is one of my favourite subjects	30.87
13	ASBM05F	**Math self-efficacy:** Good at working out hard math problems	30.68
14	ASBM01	Frequency that students work math problems independently in class (student reported)	27.00
15	ACDGSBC	School SES	26.62
16	ASBG08	School attendance	21.87
17	ASBM05E	**Math self-efficacy:** Math makes me nervous	20.62
18	ASBM02A	**Enjoy math:** Enjoy math	18.94
19	ATBM07D	Math assessment strategies: Longer tests	18.73
20	ASBM05D	**Math self-efficacy:** I learn math quickly	18.38
21	ASBG10C	**School belonging:** Feel I belong at school	18.17
22	ASBM04D	**Disorderly behaviour in math:** In math, teacher has to wait a long time for students to be quiet	17.53
23	ASBM04E	**Disorderly behaviour in math:** Students interrupt the math teacher	17.07
24	ASBM04B	**Disorderly behaviour in math:** In math, disruptive noise	17.06
25	ASBM02F	**Enjoy math:** Like schoolwork with numbers	17.04
26	ATBG09H	Teachers' classroom challenges: Too many administrative challenges	16.49
27	ASBM04F	**Disorderly behaviour in math:** Math teacher has to tell students to follow the rules	16.45
28	ASBG10B	**School belonging:** Feel safe at school	16.33
29	ASBG09B	Students feel hungry at school	16.31
30	ASBG10A	**School belonging:** Like school	16.10

Appendix E: Educational Data Mining Results

Math Anxiety (Grade 4)			
	Variable	Description	Value
	Variable	Description	Value
1	ASBM05I	**Math self-efficacy:** Math makes me confused*	153.642
2	ASBM05H	**Math self-efficacy:** Math is harder for me than other subjects*	119.088
3	ASBM05C	**Math self-efficacy:** I'm not good at math*	88.4251
4	ASSSCI01	Science plausible value (PV1)	86.7948
5	ASBM05B	**Math self-efficacy:** Math is harder for me*	54.8751
6	ATBG10A	Class size	52.6975
7	ATBM01	Math instruction time per week (teacher reported)	48.2158
8	ASBM02C	**Enjoy math:** Math is boring*	37.2609
9	ASBM02A	**Enjoy math:** Enjoy math	31.9724
10	ASBM04F	**Disorderly behaviour in math:** Math teacher has to tell students to follow the rules	30.7967
11	ASBM02I	**Enjoy math:** Math is one of my favourite subjects	30.7039
12	ASBM02B	**Enjoy math:** Wish I didn't have to do math	28.7987
13	ASBM04D	**Disorderly behaviour in math:** In math, teacher has to wait a long time for students to be quiet	26.1498
14	ASBG09B	Students feeling hungry at school	24.3052
15	ASBM04C	**Disorderly behaviour in math:** In math, too disorderly to work	23.6813
16	ASBM05F	**Math self-efficacy:** Good at working out hard math problems	23.4959
17	ASBM02G	**Enjoy math:** Like solving math problems	22.3135
18	ASBG11D	**Bullying:** Stole something	21.1311
19	ASBG08	Students' school attendance	21.0085
20	ASBG11B	**Bullying:** Left out	20.4915

21	ASBG11F	**Bullying:** Hit or hurt me	19.5743
22	ASBG11A	**Bullying:** Made fun/called names	19.568
23	ASBM04B	**Disorderly behaviour in math:** In math, disruptive noise	19.4593
24	ATBG09C	Teachers' classroom challenges: Too many teaching hours	19.4271
25	ATBM02C	Students memorize rules, procedures, facts	18.295
26	ACBG15A	Negative behaviours at school: Arriving late	18.2317
27	ACBG13AE	Shortage of instructional space	17.9211
28	ASBG10A	**Sense of belonging:** Like school	17.5768

Appendix E: Educational Data Mining Results

Confidence in Math (Grade 4)			
	Variable	Description	Value
1	ASBM05I	**Math self-efficacy:** Math makes me confused*	153.642
2	ASBM05H	**Math self-efficacy:** Math is harder for me than other subjects*	119.088
3	ASBM05C	**Math self-efficacy:** I'm not good at math*	88.4251
4	ASSSCI01	Science plausible value (PV1)	86.7948
5	ASBM05B	**Math self-efficacy:** Math is harder for me*	54.8751
6	ATBG10A	Class size	52.6975
7	ATBM01	Math instruction time per week (teacher reported)	48.2158
8	ASBM02C	**Enjoy math:** Math is boring*	37.2609
9	ASBM02A	**Enjoy math:** Enjoy math	31.9724
10	ASBM04F	**Disorderly behaviour in math:** Math teacher has to tell students to follow the rules	30.7967
11	ASBM02I	**Enjoy math:** Math is one of my favourite subjects	30.7039
12	ASBM02B	**Enjoy math:** Wish I didn't have to do math	28.7987
13	ASBM04D	**Disorderly behaviour in math:** In math, teacher has to wait a long time for students to be quiet	26.1498

14	ASBG09B	Students feeling hungry at school	24.3052
15	ASBM04C	**Disorderly behaviour in math:** In math, too disorderly to work	23.6813
16	ASBM05F	**Math self-efficacy:** Good at working out hard math problems	23.4959
17	ASBM02G	**Enjoy math:** Like solving math problems	22.3135
18	ASBG11D	**Bullying:** Stole something	21.1311
19	ASBG08	Students' school attendance	21.0085
20	ASBG11B	**Bullying:** Left out	20.4915
21	ASBG11F	**Bullying:** Hit or hurt me	19.5743
22	ASBG11A	**Bullying:** Made fun/called names	19.568
23	ASBM04B	**Disorderly behaviour in math:** In math, disruptive noise	19.4593
24	ATBG09C	Teachers' classroom challenges: Too many teaching hours	19.4271
25	ATBM02C	Students memorize rules, procedures, facts	18.295
26	ACBG15A	Negative behaviours at school: Arriving late	18.2317
27	ACBG13AE	Shortage of instructional space	17.9211
28	ASBG10A	**Sense of belonging:** Like school	17.5768
29	ATBG09A	Teachers' classroom challenges: Too many students	17.4518
30	ASBG10B	**Sense of belonging:** Feel safe at school	17.4021

Appendix F: Expert Focus Group Results

Confidence in Math										
	Variable	**Key Factor**	**Actionability**							
			Teachers	Teacher Action(s)	School Admin	School Admin Action(s)	System Admin	System Admin Action(s)	Policy/ Gov't	Policy Action(s)
1	**Enjoy math:** Math is one of my favourite subjects		Some	Teachers' dislike of math may be transmitted to students.						
2	**Enjoy math:** Enjoy math		Some	Poor instructional clarity in math may also contribute to students' like/dislike of math.						
3	Math plausible value (PV1)									
4	**Enjoy math:** Like solving math problems									
5	**Enjoy math:** Look forward to math									
6	Science plausible value (PV1)									
7	**Enjoy math:** Math is boring*									
8	**Enjoy math:** Like schoolwork with numbers									
9	Class size		No	--	Some	Where possible, allocate students to reduce class size	Yes	Allocate teachers to schools with high enrolment	Yes	Ensure sufficient educational funding
10	**Enjoy math:** Wish I didn't have to do math*									
11	**Instructional clarity in math:** Know what math teacher expects	2	Yes	Communicate math-related expectations clearly to students	Yes	Support teachers in implementing math curriculum (school-level)	Yes	Support teachers in implementing math curriculum (system-level)	Yes	Set clear expectations in math curriculum
12	**Instructional clarity in math:** Math teacher is easy to understand	1	Yes	Ongoing development of math pedagogical skills	Yes	Do walkthroughs; flag teachers who may need pedagogical support in math	Yes	Support teachers to improve their math pedagogical skills (system-level)	No	--
13	Frequency that students work math problems independently in class (student reported)		Yes	Increase the time that students work independently on math problems in class	Yes	Supervise teachers' math teaching; provide feedback on math pedagogy	Yes	Support teachers to improve their math pedagogical skills (system-level)	No	--
14	**Disorderly behaviour in math:** In math, teacher has		Yes	Implement classroom behaviour management strategies; ongoing	Yes	Support teachers with classroom management and math pedagogy	Yes	Provide pedagogical and/or behavioural supports to teachers (system-level)	Yes	Implement policies that help address classroom complexity

Confidence in Math										
	Variable	**Key Factor**	**Actionability**							
			Teachers	Teacher Action(s)	School Admin	School Admin Action(s)	System Admin	System Admin Action(s)	Policy/ Gov't	Policy Action(s)
	to wait a long time for students to be quiet			development of math pedagogical skills		development (school-level)				
15	**Disorderly behaviour in math**: In math, too disorderly to work	3	Yes	Implement classroom behaviour management strategies; ongoing development of math pedagogical skills	Yes	Support teachers with classroom management and math pedagogy development (school-level)	Yes	Develop or promote organizational policies/programs to help develop students' self-regulation skills; provide pedagogical and/or behavioural supports to teachers (system-level)	Yes	Implement policies that help address classroom complexity
16	**Bullying:** Left out		Yes	Implement strategies that support classroom inclusiveness	Yes	Encourage and develop a school culture of inclusiveness	Yes	Support teachers and school admin to enhance classroom- and school-level inclusiveness	Some	Implement policies to define what inclusive classrooms look like
17	**Disorderly behaviour in math:** Math teacher has to tell students to follow the rules		Yes	Implement classroom behaviour management strategies; ongoing development of math pedagogical skills	Yes	Support teachers with classroom management and math pedagogy development (school-level)	Yes	Provide pedagogical and behavioural supports to teachers (system-level)	Some	Implement policies that help address classroom complexity
18	**Sense of belonging:** Like school		Yes	Build community and foster inclusivity in classrooms and schools	Yes	Build community and foster inclusivity in classrooms and schools	Yes	Support teachers and school admin to develop school belonging	Yes	Track and act on student well-being; provide support to schools to enhance inclusivity
19	Teacher number of hours in formal PD for math (previous 2 years)		Yes	Elect to do math PD	Yes	Encourage teachers to attend math PD	Yes	Develop and deliver high-quality math PD	Yes	Support regional PD consortium and school board; provide funding for teachers to attend paid conferences
20	Students feel hungry at school	4	Some	Optionally provide informal supports (e.g., bring in box of granola bars)	Yes	Advocate for and implement school-level food programs	Yes	Advocate for and implement food programs	Yes	Fund and implement food programs

Appendix F: Expert Focus Group Results

Math Anxiety TIMSS Grade 4									
	Variable	**Key Factor**	**Actionability**						
			Teachers	Teacher Action(s)	School Admin	School Admin Action(s)	System Admin	System Admin Action(s)	Policy/ Gov't	Policy Action(s)
1	**Math self-efficacy:** Math makes me confused*		Some	Math pedagogical skills and teachers' own math anxiety is a factor here.						
2	**Math self-efficacy:** Math is harder for me than other subjects*									
3	**Math self-efficacy:** I'm not good at math*		Some	Promote and model growth mindset; scaffold students' developing math skills						

Math Anxiety TIMSS Grade 4										
	Variable	**Key Factor**	**Actionability**							
			Teachers	Teacher Action(s)	School Admin	School Admin Action(s)	System Admin	System Admin Action(s)	Policy/ Gov't	Policy Action(s)
4	Science plausible value (PV1)									
5	**Math self-efficacy:** Math is harder for me*									
6	Class size	2	*See Confidence in Math* (p. 38)							
7	Math instruction time per week (teacher reported)		Some	Flex math instruction time as needed to meet student needs	Some	Ensure AB Ed guidelines are met re: instructional minutes in Math.	Yes	Ensure AB Ed guidelines are met re: Instructional minutes in Math.	Yes	Set appropriate standards for minimum hours of instruction
8	**Enjoy math:** Math is boring*									
9	**Enjoy math:** Enjoy math									
10	**Disorderly behaviour in math:** Math teacher has to tell students to follow the rules	1	*See Confidence in Math* (p. 38)							
11	**Enjoy math:** Math is one of my favourite subjects									
12	**Enjoy math:** Wish I didn't have to do math									
13	**Disorderly behaviour in math:** In math, teacher has to wait a long time for students to be quiet		*See Confidence in Math* (p.38)							
14	Students feeling hungry at school		*See Confidence in Math* (p. 38)							
15	**Disorderly behaviour in math:** In math, too disorderly to work	3	*See Confidence in Math* (p. 38)							
16	**Math self-efficacy:** Good at working out hard math problems									
17	**Enjoy math:** Like solving math problems									
18	**Bullying:** Stole something		Yes	Model and promote safe and inclusive schools	Yes	Model and promote safe and inclusive schools; appropriate use of school	No	--	No	--

Math Anxiety TIMSS Grade 4										
	Variable	**Key Factor**	**Actionability**							
			Teachers	Teacher Action(s)	School Admin	School Admin Action(s)	System Admin	System Admin Action(s)	Policy/ Gov't	Policy Action(s)
						disciplinary procedures				
19	Students' school attendance	4	Some	Promote school attendance; where possible, support students who are absent due to long-term illness/hospitalization	Yes	Appropriate use of policies/procedures to promote student attendance	Yes	Develop and enact system-level policies to encourage attendance; system-level support for students with long-term illness/hospitalization	Yes	Policy support for student attendance (e.g., Minimum Attendance Rule)
20	**Bullying:** Left out		*See Confidence in Math* (p. 38)							

Appendix F: Expert Focus Group Results

Math Performance TIMSS Grade 4										
	Variable	**Key Factor**	**Actionability**							
			Teachers	Teacher Action(s)	School Admin	School Admin Action(s)	System Admin	System Admin Action(s)	Policy/ Gov't	Policy Action(s)
1	Science plausible value (PV1)									
2	**Math self-efficacy:** Math is harder for me*									
3	**Math self-efficacy:** Math is harder for me than other subjects*									
4	**Math self-efficacy:** Usually do well in math									
5	Parental education		Yes	Communicate curricular standards re: Math and student performance. Provide resources to support learning at home.	Yes	Communicate curricular standards for Math. Provide resources to support learning at home.	Yes	Communicate curricular standards for Math. Provide funding for resources to support learning at home.	Yes	Provide documents that support communication with home re: curricular standards.
6	**Math self-efficacy:** I'm not good at math									
7	**Math self-efficacy:** Math makes me confused									
8	Class size	1	*See Confidence in Math* (p. 38)							
9	Math topics covered: Comparing and drawing angles		Yes	Provide instruction on this math topic.	Some	Supervise/evaluate teachers to ensure effective math instruction.	Some	Using PAT data, provide supports to address teacher PD needs re: instruction.	No	
10	Math instruction time per week (teacher reported)		*See Math Anxiety* (p. 41)							
11	Math topics covered: Parallel and perpendicular lines		Yes	Provide instruction on this math topic.	Some	Supervise/evaluate teachers to ensure effective math instruction.	Some	Using PAT data, provide supports to address teacher PD needs re: instruction.	No	
12	**Enjoy math:** Math is one of my favourite subjects									
13	**Math self-efficacy:** Good at working out hard math problems									
14	Frequency that students work math problems independently in class (student reported)		*See Confidence in Math* (p. 38)							
15	School SES	3	No		No		Some	Provide opportunities for additional funding to support low SES schools.	Some	Ensure policy and funding is in place to support high needs and low SES schools.
16	School attendance		*See Math Anxiety* (p. 41)							

Math Performance TIMSS Grade 4										
	Variable	**Key Factor**	**Actionability**							
			Teachers	Teacher Action(s)	School Admin	School Admin Action(s)	System Admin	System Admin Action(s)	Policy/ Gov't	Policy Action(s)
17	**Math self-efficacy:** Math makes me nervous									
18	**Enjoy math:** Enjoy math									
19	**Math assessment strategies:** Longer tests	2	Yes	Design and deliver a variety of assessments to students	Some	Provide supervision and instructional leadership to ensure a variety of assessment strategies to support student learning.	Yes	Provide PD supports and resources to support a variety of assessment strategies to support student learning.	Some	Provide the policy structures to ensure effective assessment strategies occur in schools.
20	**Math self-efficacy:** I learn math quickly									

Appendix F: Expert Focus Group Results

Math Performance PISA Grade 9										
	Variable	**Key Factor**	**Actionability**							
			Teachers	Teacher Action(s)	School Admin	School Admin Action(s)	System Admin	System Admin Action(s)	Policy/ Gov't	Policy Action(s)
1	Estimation of students' performance in reading		Yes	Teachers can have Literacy intervention for students at risk.	Some	Schools can hire outside agencies to support student reading literacy by having materials about subject-specific vocabulary and tier of words.	Some		Some	
2	**Students' resilience** Students' response to the question "I usually manage one way or another."		Yes	Teachers can promote a growth mindset in students.	Yes	Schools can help with universal design for learning.	Yes	System administration can promote the same idea as schools.	Some	
3	The indication of inadequate or poor-quality educational material (e.g. textbooks, IT equipment, library, or laboratory material).		Yes	Teachers select appropriate resources to support student learning.	Yes	Provide resources to teachers	Yes	Centralizing the resources	Yes	Provide more funding
4	**Ability grouping** What is your school's policy about this for students in Grade 10 or equivalent? Students are grouped by ability within their classes.		Yes	Teachers can help organize the class with student grouping.	Yes	Schools can help with organizing math streams (e.g., high level, middle level, remedial level)	Yes	Provide PD to support ability grouping.	Yes	Provide funding/resources to support ability groupings.
5	How much do you agree with the following statement? Your intelligence is something about you that you can't change very much.		Yes	Develop a growth mindset/resilience in students.	Yes	Supervise and provide instructional leadership to encourage teacher/student growth mindset in math.	Some	Provide PD opportunities around growth mindset.	No	
6	**Staff shortage** Is your school's capacity to provide instruction hindered by any of the following issues? A lack of assisting staff.	3	Some	Advocate for more staffs	Some	Advocate for more staff, allocate staff to math classes.	Yes	The system can help allocating more educational assistant.	Yes	Provide more funding to hire more teachers.
7	**Student behaviour** In your school, to what extent is the learning of students hindered by the following phenomena? Students skipping classes		Some	Promote school attendance; where possible, support students who are absent due to long-term illness/ hospitalization	Yes	Appropriate use of policies/procedures to promote student attendance	Yes	Develop and enact system-level policies to encourage attendance; system-level support for students with long-term illness/	Yes	Policy support for student attendance (e.g., Minimum Attendance Rule)

Math Performance PISA Grade 9										
	Variable	**Key Factor**	**Actionability**							
								hospitalization		
8	**Teacher behaviour** In your school, to what extent is the learning of students hindered by the following phenomena? Teachers being too strict with students		Yes	Teachers can manage this in their teaching practice.	Yes		Yes		No	
9	**Think about your goals in school**: how true are the following statements for you? My goal is to learn as much as possible.		Yes	Teachers can support a growth mindset in students.	No		No		No	
10	**Student behaviour** In your school, to what extent is the learning of students hindered by the following phenomena? Student truancy		Some	Promote school attendance; where possible, support students who are absent due to long-term illness/ hospitalization	Yes	Appropriate use of policies/procedures to promote student attendance	Yes	Develop and enact system-level policies to encourage attendance; system-level support for students with long-term illness/ hospitalization	Yes	Policy support for student attendance (e.g., Minimum Attendance Rule)
11	**Quality assurance in school** Do the following arrangements aimed at quality assurance and improvements exist in your school and where do they come from? Regular consultation aimed at school improvement with one or more experts over a period of at least six months	1	Yes	Teachers have to be receptive to consultants. Teachers can also request support for relevant matters as well.	Yes	School administration has to be receptive to consultants.	Yes	System administration has to be receptive to consultants.	No	
12	**Student behaviour** In your school, to what extent is the learning of students hindered by the following phenomena? Students intimidating or bullying other students		Yes	Model and promote safe and inclusive schools	Yes	Model and promote safe and inclusive schools; appropriate use of school disciplinary procedures	No	--	No	--
13	**Quality assurance in school** Do the following arrangements aimed at quality assurance and improvements exist in your school and where do they come from? Systematic recording of student test results and graduation rates		Yes	Help monitoring the information at the classroom level.	Yes	Help monitoring the information at the school level.	Yes	Help monitoring the information at the system level.	Yes	Help monitoring the information at the provincial level.

Math Performance PISA Grade 9										
	Variable	**Key Factor**	**Actionability**							
14	**Student school absence** In the last two full weeks of school, how often did the following things occur? I skipped a whole school day.		Some	Promote school attendance; where possible, support students who are absent due to long-term illness/ hospitalization	Yes	Appropriate use of policies/procedures to promote student attendance	Yes	Develop and enact system-level policies to encourage attendance; system-level support for students with long-term illness/ hospitalization	Yes	Policy support for student attendance (e.g., Minimum Attendance Rule)
15	**Student behaviour** In your school, to what extent is the learning of students hindered by the following phenomena? Students not being attentive		Yes	Implement classroom behaviour management strategies; ongoing development of math pedagogical skills	Yes	Support teachers with classroom management and math pedagogy development (school-level)	Yes	Develop or promote organizational policies/programs to help develop students' self-regulation skills; provide pedagogical and/or behavioural supports to teachers (system-level)	Yes	Implement policies that help address classroom complexity
16	**Quality assurance in school** Do the following arrangements aimed at quality assurance and improvements exist in your school and where do they come from? Systematic recording of data such as teacher or student attendance and professional development		Yes	Help monitoring the information at the classroom level.	Yes	Help monitoring the information at the school level.	Yes	Help monitoring the information at the system level.	No	
17	**Teachers' level of education** The proportion of teachers with an ISCED 5A bachelor qualification		Yes	Principals can decide who to hire.	Yes	Schools regulate the hiring policy and requirements.	Yes	The system regulates the hiring policy and requirements.	Yes	The government regulates the hiring policy and requirements.
18	**Bullying at school** During the past 12 months, how often have you had the following experiences in school? I was threatened by other students.		Yes	Model and promote safe and inclusive schools	Yes	Model and promote safe and inclusive schools; appropriate use of school disciplinary procedures	No	--	No	--
19	**Student behaviour** In your school, to what extent is the learning of students hindered by the following phenomena? Student use of		Some	Advocate for student support.	Yes	Provide clear boundaries/student discipline and advocate for student support.	Yes	Support student mental health needs re: substance abuse. Support student discipline processes.	Yes	Provide resources and funding to support student health concerns.

Math Performance PISA Grade 9										
	Variable	**Key Factor**	**Actionability**							
	alcohol or illegal drugs									
20	**Quality assurance in school (collaboration among teachers)** Do the following arrangements aimed at quality assurance and improvements exist in your school and where do they come from? Implementation of a standardized policy for reading subjects	2	Yes	Actively participate in PD opportunities and professional reflection re: assurance measures.	Yes	Schools can manage this issue internally.	Yes	Provide targeted PD opportunities for teachers. Approve and support training re: instructional materials and resources.	Some	Approve and support the implementation of high-quality instructional materials.