PREDICTORS OF GRADE 9 MATHEMATICS ACHIEVEMENT WITH IMPLICATIONS FOR OPTIMAL PEDAGOGY

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Abstract

Interest is rapidly growing in providing social-emotional supports to students to enhance academic achievement. This paper examines how data in a school authority's Student Information System can be used to address schools' questions regarding factors associated with student achievement. Potential cognitive, behavioural and non-cognitive predictors of Grade 9 achievement in mathematics were analyzed using past achievement and school attendance data, as well as facilitators of student engagement measured via web-based Student Orientation to School Questionnaire (SOS-Q). The findings suggest that students struggling with Math 8 should be given the option of taking a pre-Math 9 course prior to enrolling in the regular Math 9 course. Also, cultivating external resilience and self-confidence in students would contribute to strategies to reduce math anxiety. Classification of students according to their individual social-emotional, behavioural and academic achievement traits reveals diverse manifestations of these characteristics in different groups of students and illustrates the need for comprehensive supports customized to the specific needs identified for each student.

Keywords: Student affect and achievement, accurate predictors of student achievement, Math anxiety and achievement

Introduction

Interest is rapidly growing in providing social-emotional learning supports to students at all education levels to enhance academic achievement. A related area of growing attention is the measurement and diagnosis of student engagement with school. There is growing awareness that we can use enhanced data analytics to improve education by assessing non-cognitive motivators of academic outcomes [1], [2]. These often not easily detectable affective motivators are complex and include, for example, a student's sense of self-confidence, resilience and belonging.

Two camps have emerged on measuring student engagement; one focused on measuring engagement at the cohort level, and another explores measuring engagement at the individual student level. Our research concentrates on the latter approach. In the past decade research on student social-emotional connectivity to school has demonstrated how schools can reengage the disaffected student as a strategic support for enhanced achievement and equal educational opportunity [1]. For example, the study, *PISA 2012 Results in Focus: What 15-year-olds know and what they can do with what they know* [3], concluded that, "…drive, motivation and confidence in oneself are essential if students are to fulfil their potential" (p. 21). The OECD authors further recommended that, "Teachers and school principals need to be able to identify students who show signs of lack of engagement with school and work with them individually before disengagement takes firm root" (p. 22).

The Student Orientation to School Questionnaire (SOS-Q)

Educators need to better understand why students may struggle with school and explore different avenues for creating safe and supportive school environments conducive to student engagement. This would include identifying at risk students and developing effective interventions [4]. While student achievement is an important indicator of ultimate success at school, key research indicates that academic performance is affected by social and emotional factors [5], [6], [7], [8], [9], [10]. Awareness of dynamic student needs by school staff would improve if school and district data collections extend beyond achievement and behavioral data, which mostly measure student "outcomes," to assessing possible social-emotional facilitators of these outcomes. Thus student support strategies would be better informed by an integrated student data collection model where measures of academic achievement and behavior (e.g., attendance) are supplemented by diagnostic non-cognitive measures of student affect.

Valid and reliable measurement of social and emotional experiences of students was the rationale behind the development of the Student Orientation to School Questionnaire (SOS-Q). Both elementary and junior/senior high versions of the instrument measure five key factors or constructs: Peer Relationships, Self-Confidence as a learner, Safe and Caring School, Internal Resilience and External Resilience. The junior/senior version also measures Extracurricular Activities and Utility of School, and if a student works outside of school then School-Work Balance and School-Work Integration are also measured. The SOS-Q is a comprehensive, yet succinct instrument, which is easily applicable in busy school settings. The SOS-Q constructs are defined as follows:

- Safe and Caring School – students' perception of how supportive the school environment is, including caring relationships with teachers

- External Resilience – perceived ability to cope with external challenges and adversities

- Internal Resilience – perceived ability to resist anxiety and maintain emotional balance

- Extracurricular Activities – participation and perceived value

- Self-Confidence – conviction of capability to be successful at school and beyond

- Utility of School – sense of usefulness of school in relationship to future opportunities

- Peers – ability to get along with other students and perceived friends' support.

The SOS-Q scale items are rated on a 5-point Likert-type scale, with response options ranging from "strongly agree" to "strongly disagree."

Assessing student disposition towards school using SOS-Q draws attention to the development of subsequent student support strategies. Previous work has described the development of the SOS-Q as well as its construct and predictive validity [11], [12].

Math Anxiety and Math Achievement

Math anxiety has long been known to be an affective factor that influences math achievement. Gunderson, Park, Maloney, Beilock and Levine [13] propose that social-emotional factors play a key role in math anxiety linked to motivational frameworks that influence early math skills in a reciprocal manner. They have defined math anxiety as, "a negative affective reaction to situations involving math" (p. 21). Math anxiety seems to be specific to the math domain independent of other academic domains and can create worries that can interfere with working memory thus suggesting a complex social- emotional – cognitive connection [14].

Antecedents to math anxiety or factors that may have a causal relationship can include both parental and teacher math influence on students, as well as societal pressure and stereotypes such as those found in high-stakes academic cultures that vary in cross-national contexts [14]. Such antecedents are external to students and are less amenable to direct and short term interventions and learning improvement strategies, thus pointing to the utility of a research focus on direct student-centered diagnostics, interventions and supports.

Math anxiety presents across a broad range of student age groups, from early elementary to junior high and high school [13], [15], [16]. Meece, Wigfield & Eccles [17] found that students' current performance expectances and perceived importance of math had strong direct effects on anxiety. Gunderson et. al. [13] concluded that early individual differences in math achievement exist differentially relative to student gender, with female students typically having higher anxiety, but for all students math achievement can grow into later disparities influenced by reciprocal social-emotional effects, motivational frameworks and anxiety.

Meece, Wigfield & Eccles [17] suggest that for students with poor math achievement, skill development linked with training to reshape negative motivation patterns may be the most effective approaches to enhancing math achievement. They suggest that teachers can enhance students' valuing of math as an intermediary of math anxiety by linking the value of math to students' everyday lives, making math personally meaningful and alerting students to the importance of math to career paths. It is clear that research has consistently supported investigating the complex reciprocal relationships between math achievement as mediated by student engagement with school and factors associated with math anxiety.

The Present Study

The study reported here analyzed cognitive, behavioural and non-cognitive predictors of achievement in Grade 9 Mathematics for a grade 9-12 high school in an intermediate size suburban school jurisdiction in Alberta, Canada. The school's staff was interested in working with the researchers to investigate why 28% of 162 Grade 9 students failed Math 9 at the end of the first semester of the 2017-18 school year, whereas only 9% of 154 Grade 9 students who completed Language Arts 9 did not pass.

Participants and Measures

To unpack this differential in achievement we investigated potential predictor variables available in the school jurisdiction's Student Information System, including the previous year school attendance (in 2016-17) and previous achievement data, including standardized provincial test data on Grade 6 Math and teacher assigned marks at the end of Grade 8. Past achievement data were located for 125 of the students when in Grade 6, and 140 students when in Grade 8. SOS-Q affective data were also captured in March of 2018 for 107 students from the 2017-18 Grade 9 Math cohort.

Analytics

The data were analyzed using SPSS V. 25. Multiple linear regression analysis was applied to determine how previous year school attendance and past math achievement was associated with current achievement in Grade 9 Mathematics, which was assessed by teachers in the classroom. Multiple linear regression was also applied to analyze how the pattern of school engagement as measured by the SOS-Q can illuminate optimal pedagogical support strategies for improving mathematics achievement.

Results

Given that attendance data and classroom-based achievement data for previous math results for the 2015-16 and 2016-17 school years as well as for the provincial standardized math achievement test for 2014-15 were all available in the Student Information System, we were interested in which of these variables would be the strongest predictors of classroom achievement in the Math 9 course students had recently completed. Tables 1 and 2 display the descriptive statistics for the above-mentioned variables and the results of multiple linear regression.

Table 1. Descriptive Statistics of Achievement in Mathematics and School Attendance.

	Mean	Standard. Deviation	N
Classroom-Based Math 9 Mark (%): 2017-18	59.07	19.21	163
Classroom-Based Math 8 Mark (%): 2016-17	73.83	13.10	140
Math 6 Standardized Provincial Achievement Test (PAT) (%): 2014-15	56.54	17.24	125
Attendance (% of School Days Attended): 2016-17	90.78	9.93	167

Table 2. Classroom-Based Grade 9 Math Achievement Predicted by Previous Achievement and Attendance.

Dependent Variable: 2016-17 Classroom-Based Grade 9 Math	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Constant	-52.411				
Classroom-Based Math 8 Mark (%): 2016-17	.866	.087	.668	10.231	.000
Math 6 Standardized Provincial Achievement Test (PAT) (%): 2014-15	.205	.063	.196	3.224	.002
Attendance (% of School Days Attended): 2016-17	.393	.34	.156	2.927	.004
R Square = .74, Adjusted R Square = .73					

Note: N = 119 (listwise deletion).

The linear regression model indicates that classroom-based Math 8 achievement was a strong positive predictor of classroom achievement in Math 9. On average, keeping other predictors constant, for every 1% increase in Math 8 mark the model predicts an increase of .87% in Math 9 mark. The outcomes of a more distant back in time Grade 6 standardized Provincial Achievement Test (PAT) showed a more modest, but significant positive predictive effect, where a 1% increase in the Grade 6 PAT scores would be associated with a .21% higher classroom Grade 9 Math mark. The results of linear regression also support the importance of the attendance history, where (keeping other independent variables constant) a 1% higher attendance in the previous school year would be associated with a .39% higher Grade 9 Math classroom mark. Next, we were interested in how social-emotional factors as measured by the SOS-Q may predict Math 9 achievement. One hundred and seven students completed the SOS-Q in March 2018, shortly after completing the first semester Math 9 course. The descriptive statistics for each of the SOS-Q constructs is presented in Table 3.

Table 3. Descriptive Statistics – SOS-Q Predictors of Math 9.

SOS-Q Subscales	Mean Scale Score (on a 5-point scale)	Std. Deviation	N
Self-Confidence	3.79	.71	107
Extracurricular Activities	3.27	.80	107
Safe and Caring School	3.64	.57	107
External Resilience	3.67	.54	107
Internal Resilience	2.45	.85	107
Utility of School	3.67	.85	107
Peers	3.97	.69	107

Previous research [12] had indicated that the Self-Confidence and Extracurricular Activities variables would have the strongest predictive power for achievement, therefore, these two constructs were entered first in a linear multi-regression model (see Table 4). The remaining SOS-Q constructs were entered next. As anticipated, Self-Confidence demonstrated a strong predictive relationship with Math 9 achievement in Model 1, but when the other SOS-Q constructs were added in Model 2, External Resilience demonstrated a strong predictive relationship with Math 9 achievement where, keeping all other predictors constant, a 1 point gain in External Resilience on the SOS-Q 5-point scale would result in an 11.1% increase in classroom-based Math 9 achievement mark.

Table 4. Classroom-Based Grade 9 Math Achievement Predicted by Student Orientation to School.

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	Constant	30.547				
	Self-Confidence	8.640	2.592	.327	3.333	.001
	Extracurricular Activities	2.955	2.277	.127	1.298	.197
	R Square = .16; Adjusted R Square = .14					
2	Constant	29.107				
	Self-Confidence	4.071	3.937	.154	1.034	.304
	Extracurricular Activities	2.045	2.426	.088	.843	.401
	Safe and Caring School	-.994	4.947	-.030	-.201	.841
	External Resilience	11.145	4.797	.320	2.323	.022
	Internal Resilience	.879	2.133	.040	.412	.681
	Utility of School	.600	3.360	.027	.178	.859
	Peers	-4.640	2.904	-.169	-1.598	.113
	R Square =.219; Adjusted R Square = .164					

Note: The independent variables were centered on the minimum value of SOS-Q scores = 1.

Dynamics of Students' Affective, Behavioral and Achievement Attributes

In order to illustrate the importance of individualized approaches to developing strategies to improve student engagement in school, attendance and achievement, we classified individual students using their measures on the above-discussed Student Orientation to School Questionnaire, previous year attendance and Grade 9 Math achievement variables using k-means cluster analysis. Fig. 1 shows three clusters or groups of students who conveyed very different affective, behavioral and academic characteristics. Mean scores on the SOS-Q scale, as well as student attendance and Grade 9 achievement scores are exhibited on the chart as standardized z scores. All mean values are at zero level and the differences below and above the mean are shown in standard deviations.
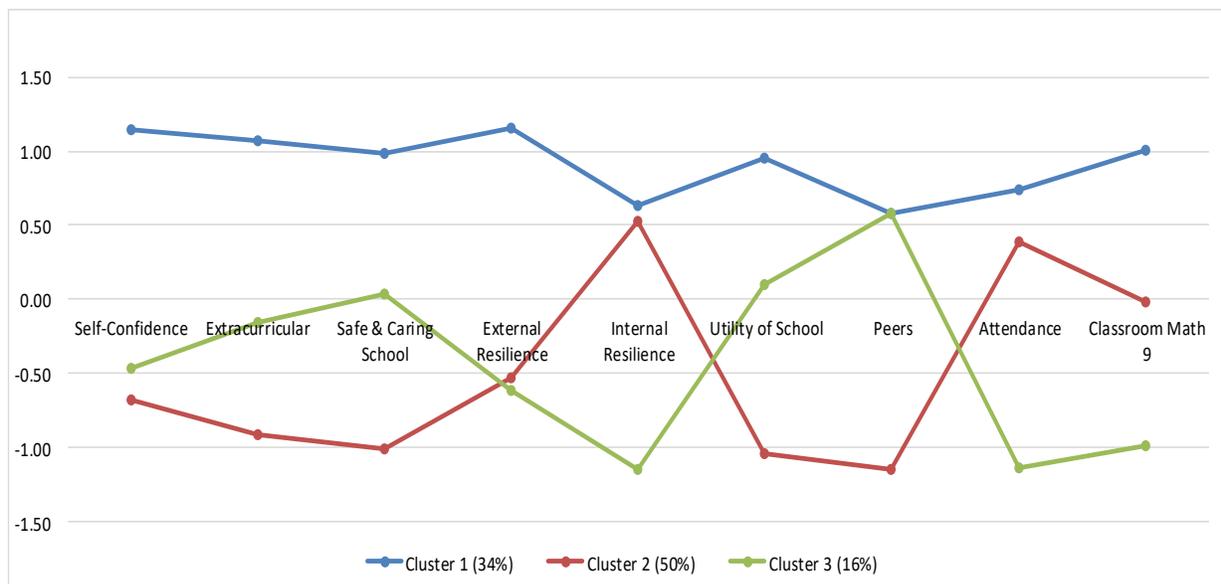

Fig.1. Grade 9 Students Classified in Three Clusters

While a third of the Grade 9 students grouped in Cluster 1 demonstrated uniformly positive stance on all of the orientation to school dimensions, as well as above average attendance and achievement, their other counterparts displayed more complex combinations of attitudes, behaviour and academic outcomes. For example, students in Cluster 2 (half of all students) scored below average on each of the SOS-Q constructs, except for relatively high internal resilience. They also had above average attendance levels and average math achievement. This could be a warning sign that a large proportion of students may be disaffected with school, but still maintaining acceptable attendance due to different reasons or motivations (which could be family pressure, desire to complete school or other motivations). Finally, a small group of students in Cluster 3 (16%) while being not negative towards school, were low on resilience and self-confidence and showed the lowest school attendance and math achievement levels. Their positive disposition towards peers may have a negative connotation given other aspects of their profile (peers may have a positive or negative effect on attitudes towards school, behavior and achievement).

In all, a cluster analysis, which can yield more detailed and complex sets of student clusters, illustrates the necessity of customized approaches when trying to help students being successful at school. Complex social, behavioural and academic issues experienced by students warrant development of complex data collection systems capable of capturing these experiences and early detection of problems.

Discussion and Conclusions

The above analyses demonstrate the utility of using value-added analytics based on the data available in a school authority student information system to provide insight into cognitive, behavioural and affective factors that can predict student achievement in specific subjects. One recommendation that emerges from the data analyses suggests that when students enter the high school and before enrolling in Math 9 attention should be given to the student's previous year results. If the student has struggled with Math 8 then they should be given the option of taking pre-Math 9 course designed to teach the cognitive entry characteristics required for success in Math 9 [18].

The "unexpected" (relative to previous findings using SOS-Q data) result of External Resilience demonstrating the strongest predictive power relative to Math 9 achievement complements the existing research-based knowledge associated with the SOS-Q. This finding corroborates the proposition that the relative strength of the SOS-Q predictors may vary depending on local circumstances (such a school environment) or student characteristics (such as age, socio-economic background and other individual or cohort traits). When incorporating students' social-emotional state into developing strategies to improve achievement in mathematics, it makes sense to consider External Resilience, a measure of a student's perceived ability to cope with external challenges and adversities, in conjunction with Self-Confidence, a students' conviction of their capability to be successful at school and beyond. Self-Confidence did emerge as a strong predictor of academic achievement in previous studies based on different data sets. Based on the individual student SOS-Q profile an intervention plan should be constructed with the students and their parents to build resilience and confidence as a learner and to reduce anxiety that may be generated by the challenges that math courses may present.

The combined cognitive and affective personalized support program tailored to the individual student's needs has the potential to make all the difference in the world for the student's ultimate success in school. The results of cluster analysis demonstrate how different groups of students or individual students can vary in terms of combinations of their attitudes, behaviors and academic traits. Comprehensive student information systems designed to capture social-emotional variables along with the behavioural and cognitive components, combined with regular diagnostic data analytics, would make it possible for educators to know their students better, uncover unarticulated "unexpected" issues and address students' needs on an individual basis.

The utility of student data and data analytics designed to answer questions about factors that may affect student engagement and achievement do point to the importance of maintaining accurate and comprehensive data within student information systems in school authorities.

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