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Parents' Education Level in Students' Mathematics Achievement; Do School Factors Matter?

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INTRODUCTION

Educational achievement in middle grades serves as a strong indicator for student's success in secondary and post secondary education. However, achievement in middle school education could be attributed to a complex and dynamic interaction among plethora of variables. For example, Harnischfeger and Wiley (1976) developed a model of school learning with six components in three categories: *background* which includes curriculum, institutional factors, and teachers and students characteristics, *teaching learning process* which includes homework, in-class and out-of-class activities, *acquisition* which is student achievement.

Overall, a multitude of literature was found to address the relation between student factors, school factors, family factors, etc. and students' mathematics achievement at various levels. Some researchers have sought the effect of single factors (e.g. class size, gender) on achievement while most of the researchers have sought the effect of several factors on achievement simultaneously. TIMMS 2003 data set gives a rear opportunity to researchers to investigate the effect of school level aggregate variables on mathematics and science achievement. In particular, it provides three school level variables; **available resources for mathematics instruction** which is a combination of many variables such as text books, supplies, infrastructure, computers, and reference materials; **good school and class attendance** which is a combination of arriving late at school, absenteeism, and skipping classes; and **principals' perception of school climate** which is a combination of teacher satisfaction, teachers' understanding of the school's curricular goals, teachers' degree of success in implementing the school's curriculum, teachers' expectations for student achievement, parental support for student achievement, parental support for school activities, student regard for school property, and student desire to well in school. TIMSS 2003 led to the publication of many research reports. Surprisingly, there is little or no research on the effect of these school level aggregate variables on student mathematics achievement. This might probably be due to the fact that these variables are not specifically situated within existing literature. However, it may be important to school leaders to know the effect of these school level variables in students' mathematics achievement. In order to achieve these research objectives, three research questions guided this analysis:

1. Do the student factor: parents' education level significant predictor of student math-achievement?
2. Do the school factors: principals' perception of school climate, availability of school resources for mathematics instructions, and good school and class attendance explain differences in mathematics achievement among schools?
3. Do school factors reduce the effect of student factors in student math-achievement?

Literature Review

Research has indicated a positive relationship between education level of the parents and the student performance in mathematics (Education Matters 2004). Also, variables closely related to level of

parental education such as income, occupation, and socioeconomic status consistently have been shown to have a direct positive association with student math achievement (Ma and Kishor 1997, Ma 2000, Schreiber 2002).

School resources that have been researched to understand students' mathematics achievement are class size, teacher quality, calculators, computers and computer software, text books etc. Small class rooms, in particular in elementary and middle school level, has shown to be beneficial to student achievement in mathematics (Pong and Pallas 2001; Nye et al.'s 2004). Teachers with four characteristics, or dimensions, of teacher quality consistently generate higher student achievement in mathematics: content knowledge, experience, teacher training and certification, and general cognitive skills (Goldhaber and Brewer 1997; Ascher & Fruchter, 2001; LaTurner 2002). The general relationship between computer-assisted instructions is based on the concept that technology makes learning easier, more efficient and more motivating. Research has found that utilizing computer-assisted instructions improved instruction and increased mathematics achievement significantly (Traynor 2003). Many studies have been completed attempting to determine the effect of text-books on mathematics achievement under the context of opportunity to learn because opportunity to learn is considered an important contributing factor in learning outcomes (Haggarty & Pepin 2002). An item based analysis of textbook contents shown fairly high positive correlations with student performance at the item level in TIMSS 1999 (Jukka 2005).

The components of good school and class attendance variable are arriving late at school, absenteeism, and skipping classes. Student absenteeism can have a negative effect on a student's opportunity to learn and may be harmful to a student's learning achievement. School absences have been found to be related to a number of important outcomes, including subsequent school dropout (Howard and Anderson, 1978), and student school performance or achievement (Monkand Ibrahim, 1984). Studies show that higher attendance is related to higher achievement for students of all backgrounds (Epstein and Sheldon 2002).

Positive association between teachers' expectations and mathematics achievement has been observed. Over the years, attention has generally focused on teachers' expectations and achievement gap among students of different racial groups. In a recent study, Terrell (2008) observed a significant positive association between teacher expectations and urban black male's success in mathematics and science. Researchers have had varying results when examining whether teacher satisfaction or motivation leads to increased levels of academic achievement. For example, Stevens & White (1987) studied the records of students in 15 school districts with 191 teachers as subjects and summarized that there was no direct relationship between teacher morale and student achievement. However, in a study related to Cambodia fourth grade teachers and students, Chhinh and Tabata (2003) have found a statistically significant relationship between job satisfaction and mathematics achievement. Parental support for student achievement as well as parental involvement in school activities has had a positive impact in student academic success (Hoover-Dempsey & Sandler, 1995). The results of a recent cross national study (USA, China) by Cai (2003) involving sixth grade students support the argument that parental support is a statistically significant predictor of their children's mathematics achievement.

METHOD

Sample and study variables The data for this research is drawn from the Third International

Mathematics and Science (TIMMS 2003) database. The database comprises student achievement data in mathematics and science as well as student, teacher, school, and curricular background data for the 48 countries that participated in TIMMS 2003 at the eighth grade and 26 countries at the fourth grade. The sample for this study is the eighth grade U.S. students. A total of 8500 U.S. eighth graders from 232 schools participated in TIMMS 2003.

The mathematics assessment for TIMSS was framed by two organizing dimensions; a content dimension and a cognitive dimension. Mullis et al., 2003 I.V.S. Mullis, M.O. Martin, T.A. Smith, R.A. Garden, K.D. Gregory and E.J. Gonzalez *et al.*, TIMSS assessment frameworks and specifications 2003, Boston College, Chestnut Hill, MA (2003). There were five content domains: number, algebra, measurement, geometry, and data, and three cognitive domains: knowing facts and procedures, using concepts, solving routine problems, and reasoning. TIMSS used item response theory (IRT) methods to summarize the achievement results. Treating equally all the countries that participated, the TIMSS scale average over those countries was set at 500 and the standard deviation at 100.

TIMMS database contains range of derived variables that summarized the data in ways that highlighted the relationship with mathematics achievement. The derived variables used in this study are index of highest level of education of either parent (**PEL**), index of availability of school resources for mathematics instructions (**ASRMI**), index of principals' perception of school climate (**PPSC**), index of good school and class attendance (**GSCA**).

The index PEL is computed from students' response to the following two separate questions: What is the highest level of education completed by your mother (or stepmother or female guardian)? What is the highest level of education completed by your father (or stepfather or male guardian)? The index PEL is assigned to five levels as follows

- 1 = Finish University or Equivalent or Higher
- 2 = Finish Post-secondary Vocational/Technical Education But Not University
- 3 = Finish Upper Secondary Schooling
- 4 = Finish Lower secondary Schooling
- 5 = No More than Primary Schooling

The index ASRMI is computed from principals' responses to questions regarding shortages or inadequacies that can affect instruction in their school on a four point likert scale (1 = none, 2 = a little, 3 = some, 4= a lot):

Is your school capacity to provide instruction affected by a shortage or inadequacy of any of the following?

- a = Instructional materials (e.g., textbook);
- b = Budget for supplies (e.g., paper, pencils);
- c = School buildings and grounds;

d = Heating/cooling and lightening systems;

e = Instructional space (e.g., classrooms);

g = Computers for mathematics instruction;

h = Computer software for mathematics instruction;

i = Calculators for mathematics instruction;

j = Library materials relevant to mathematics instruction;

k = Audio-visual resources for mathematics instruction.

Index ASRMI is assigned to three levels as follow:

1 = high: Average value of a-e is less than 2 AND the average value of g-k is less than 2;

3 = low: Average value of a-e is greater than or equal to 3 AND the average value of g-k is greater than or equal to 3;

2 = medium: All other combinations.

The index PPSC is computed from principals' responses to eight questions regarding school climate using a four point likert scale (1 = very high, 2 = high, 3 = medium, 4 = low, 5 = very low). How would you characterize each of the following within your school?

a = Teachers' job satisfaction

b = Teachers' understanding of the school's curricular goals

c = Teachers' degree of success in implementing the school's curriculum

d = Teachers' expectations for student achievement

e = Parental support for student achievement

f = Parental involvement in school activities

g = Students' regard for school property

h = Students' desire to do well in school

Index is calculated by averaging the responses for the above eight categories and assigned to three levels as follow:

1 = High: Average value is less than or equal to 2

2 = Medium: Average value is greater than 2 AND less than or equal to 3

3 = Low: Average value is greater than 3

The index GSCA is computed from principals' responses to two questions concerning the problem behaviors of students in their schools: How often each of the following behavior occurs among eighth grade students in your school? Using a 5 point likert scale: 1) Never, 2) Rarely, 3) Monthly, 4) Weekly 5) Daily.

If the behavior occurs, how severe a problem does it present? Using a 3-point likert scale: 1) Not a problem, 2) Minor problem, 3) Serious problem

a = Arriving late at school

b = Absenteeism (i.e., unjustified absences)

c = Skipping class (hours/periods)

Index GSCA is assigned to the usual three levels 1=High, 2=Medium and 3=Low.

For the convenience of analysis and interpretation values of student level variable PEL is reversed and then centered on its school mean. For the same reason, the three school levels indices (ASMRI, PPSC, and GSCA) are converted as follows: 1=High, 0=Medium, -1=Low.

Analysis: (Part1)

In order to investigate the student and school factors associated with variance in mathematics achievement scores, it was necessary to use multilevel modeling techniques (Bryk & Raudenbush 1992). Multilevel modeling is a development of the common statistical technique of regression analysis. Multilevel modeling acknowledges that data are often grouped into clusters at several levels. For example, with the TIMSS data, students are grouped within classes, within schools. Multilevel modeling allows us to take this hierarchical structure into account and produce more accurate predictions and estimates.

Hierarchical linear modeling is usually carried out in three stages. Step 1: assume no covariates for both student and school levels. This model is known as unconditional mean model. The unconditional mean model facilitates examining variation in mathematics achievement across schools. Step 2: assume covariates for student level for student level model and covariates for school level for school level model. The objective is to identify statistically significant variables at these two levels. Step 3: assume covariates, those found to be statistically significant in state 2, for both school and student level simultaneously.

Unconditional mean model: (Assume no covariates for both student and school level)

Level 1 or student level is: $Y_{ij} = \beta_{0j} + r_{ij}$

At Level 2 or school level, each school mean math achievement β_{0j} is represented as a function of the grand mean γ_{00} plus a random error: $\beta_{0j} = \gamma_{00} + u_{0j}$

By combining these two:

$$Y_{ij} = \underbrace{\gamma_{00}}_{Fixed} + \underbrace{u_{0j} + r_{ij}}_{Random}, \quad \text{where } u_{0j} = N(0, \tau_{00}) \quad \text{and } r_{ij} = N(0, \sigma^2)$$

Y_{ij} : Math-achievement of student i in school j , γ_{00} : Average school mean math-achievement for the population of schools, τ_{00} : school-level variance, σ^2 : student-level variance.

Student-level model: (Assume covariates for student level)

Student level: $Y_{ij} = \beta_{0j} + \beta_{1j}PEL_{ij} + r_{ij}$ where PEL is in fact centered on its school mean.

School level: $\beta_{0j} = \gamma_{00} + u_{0j}$ and $\beta_{1j} = \gamma_{10} + u_{1j}$

Combining these two:

$$Y_{ij} = \underbrace{\gamma_{00} + \gamma_{10}PEL_{ij}}_{Fixed} + \underbrace{u_{0j} + u_{1j}PEL_{ij} + r_{ij}}_{Random}$$

Where $r_{ij} = N(0, \sigma^2)$ and $\begin{pmatrix} u_{0j} \\ u_{1j} \end{pmatrix} = N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \tau_{00} & \tau_{01} \\ \tau_{10} & \tau_{11} \end{pmatrix}\right]$

This model assume not only that student math-achievement is related to student level predictor, but also that the relationship between student level predictor and math-achievement can vary across schools.

School-level model: (Assume covariates for school level)

Student level: $Y_{ij} = \beta_{0j} + r_{ij}$

School level: $\beta_{0j} = \gamma_{00} + \gamma_{01}PPSC_j + \gamma_{02}GSCA_j + \gamma_{03}ARSMI_j + u_{0j}$

Combining these two:

$$Y_{ij} = \underbrace{\gamma_{00} + \gamma_{01}PPSC_j + \gamma_{02}GSCA_j + \gamma_{03}ARSMI_j}_{Fixed} + \underbrace{u_{0j} + r_{ij}}_{Random}, \quad \text{where } u_{0j} = N(0, \tau_{00}) \quad \text{and } r_{ij} = N(0, \sigma^2)$$

[Table 1: Results for unconditional mean, student level, and school level models

	Unconditional mean model		Student Level model		School Level model	
	Estimate	SE	Estimate	SE	Estimate	SE
<i>Fixed Effects</i>						
γ_{00}	501.79	3.36	504.01	3.42	494.26	4.30
γ_{10} (PEL)			11.10	0.76		
γ_{01} (PPSC)					31.17	5.28
γ_{02} (GSCA)					17.09	5.92
γ_{03} (ARSMI)					0.89*	5.94
<i>Random Effects</i>						
τ_{00}	2504.23	243.14	2582.60	252.58		
τ_{10}			179.77	42.04		
τ_{11}			26.78	11.85		
...2	3766.66	57.17	3562.92	61.23		

σ^2	3766.66	31.17	-----	-----
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Results for the analysis of unconditional mean model appears in first column of Table 1. The average schools mean math-achievement for the population of school is 501.79 with a standard error of 3.36. The student level variance is $\sigma^2 = 3766.66$. The school level variance or variance of the school means around the grand mean is $\tau_{00} = 2504.23$. The hypothesis tests indicate that both variance components are significantly different from zero. These estimates suggest that schools differ in their average mathematics achievement and there is even more variation among students within schools. This also justifies the use of hierarchical linear modeling in analysis of this data set.

Results for the student level model appear in second column of Table 1. The average regression equation within schools is $y_{ij} = 504.01 + 11.10PEL_{ij}$. The student level variable, parents' education level $\gamma_{10} = 11.10$, is a significant predictor in student math-achievement. PEL explains $\frac{(3766.66 - 3562.92)}{3766.66} = 0.054$ or 5.4% of within school variation in student level math-

achievement. The estimated variance of the slope $\tau_{11} = 26.78$ is statistically significant. This means that the relationship between PEL student math-achievement within schools varies significantly across the population of schools.

Results for the school level model appear in third column of Table 1. The results show a significant association between the index of principals' perception of school climate and school level math-achievement $\gamma_{01} = 31.17$; index of good school and class attendance and school level math-achievement $\gamma_{02} = 17.09$ and statistically non-significant association between index of availability of school resources for mathematics instructions and school level math-achievement $\gamma_{03} = 0.89$.

Analysis: (Part2): Two-level (Student-School) hierarchical linear model with student-level variable at the first level and school-level variables (found to be significant in part 1) at the second level.

$$Y_{ij} = \underbrace{\gamma_{00} + \gamma_{10}PEL_{ij} + \gamma_{01}PPSC_j + \gamma_{02}GSCA_j + \gamma_{11}PPSC_j \cdot PEL_{ij} + \gamma_{12}GSCA_j \cdot PEL_{ij}}_{Fixed} + \underbrace{+u_{0j} + u_{1j}PEL_{ij} + r_{ij}}_{Random}$$

Table 2: Results for 2-Level model

	With interactions		Without interactions	
	Estimate	SE	Estimate	SE
<i>Fixed Effects</i>				
γ_{00}	497.38	3.51	498.27	3.48
γ_{10} (PEL)	10.08	0.94	10.86	0.84
γ_{01} (PPSC)	30.67	5.20	27.84	4.98
γ_{02} (GSCA)	17.31	5.96	18.05	5.72
γ_{11} (PPSC*PEL)	2.59*	1.39		
γ_{12} (GSCA*PEL)	-0.82*	1.68		
<i>Random Effects</i>				
τ_{00}	1726.82	190.48	1728.17	190.74
τ_{10}	143.78	38.52	141.68	38.31
τ_{11}	28.92	12.71	27.28	12.59
σ^2	3485.66	65.50	3487.15	65.56

Results for the student-school level model appear in Table 2. The interaction terms $\gamma_{11} = 2.59$ and $\gamma_{12} = -0.82$ which are differentiating effect of principals' perception of school climate on parents' education level and good school and class attendance on parents' education level are not statistically significant. The model was then run without interaction terms and results appear in second column of Table 2.

DISCUSSION

The student level variable, parents' education level, is significantly positively related to student math-achievement and this factor observed to be significantly varies across population of schools. For example, on average, a student whose parents' education level is *Finish University or Equivalent or Higher* scored $2 \times 10.86 = 21.92$ points higher than a student in the same school whose parents' education level is *Finish Upper Secondary Schooling*. However, PEL explains only 5.4% of within school variation in math-achievement. This indicates that the success of many students appears to be dependent on factors other than their parents' level of education. These results are common in traditional math-achievement literature (Education Matters, December 2004).

The school level factors; principal's perception of school climate, good school and class attendance; significantly increases the school level math-achievement. However, school resources for mathematics instruction found to be non-significant factor in school level math-achievement. For example, controlling for GSCA, on average, a school with *high* principal's perception in school climate scored $2 \times 27.84 = 55.78$ points higher than a school with *low* principal's perception in school climate. Similarly, controlling for PPSC, on average, a school with *high* value for GSCA index scored $2 \times 18.05 = 36.10$ points higher

than a school with *low* value for GSCA index. Given the fact that the average school level math-achievement is around 500, these two factors are not only statistically significant but also practically important. The non significant relation between ASRMI and achievement is contrary to what was found in recent literature (Traynor 2003; Jukka 2005). This may be explained by the frequency distribution of ASRMI. Low=2%, Medium=47%, and High=51%. Only 2% of the schools have reported that school capacity to provide instruction affected by a shortage or inadequacy of the resources. This can be interpreted as though a certain amount of resources are necessary for the success in mathematics learning much more resources do not increase achievement.

Results of student level model show a significant variability in PEL coefficient across population of schools. This indicates that in some schools parents' education level has a weak relationship with student math-achievement. This variation could have been due to numerous factors such as school size, class size, and school type, etc. Therefore, the important question is whether any of the school level factors PPSC or GSCA reduces the PEL coefficient. In other words, do PPSC and/or GSCA help identify not only more effective schools but more equitable schools also? Interaction terms in student-school level model are not statistically significant. Hence, none of the PPSC or GSCA helps identify more equitable schools. In other words, **the results do not support the hypothesis** that parents' education level has differential influence on achievement depending on the level of PPSC or GSCA values.

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