Multilevel Analysis Approach for Determining 8th Grade Mathematics Achievement in the State of Kuwait [1]

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Abstract

The purpose of this study was to determine the magnitude of the effects of students' level variables and school level variables in predicting the 8th Grade students' achievement in Mathematics in the State of Kuwait by using Hierarchal Linear model (HLM) strategy. A sample of 865 eight-graders and their parents has participated in this study. Furthermore a stratified sample of 37 schools together with their principals and mathematics teachers were involved in the study. The assessment battery of mathematics test, students', teachers', and schools' questionnaires were used for the purpose of collecting data.

The findings of this study revealed that the variation within schools is higher than the variation between schools, which means that the student-level variables such as prior achievement and academic self-concept in predicting mathematics achievement are more important than school-level variables.

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Researchers in psychology and education have always been interested in determining differences inter and intra-individuals in order to investigate causes and/or effects of some variables (independent) on other variables (dependents), knowing that the individual is the one who decides the outcome of the treatment. It is his nature and the nature of the interaction among his personal variables on one side, and family, and school factors on the other side, which decides how he receives, assimilate, react to the treatment, and produce the behavioral changes. Therefore, researchers should evaluate this interaction when it comes to analyzing their research data. Such interaction creates contextual environment, where each individual has his own domain. Many studies and researches; however, consider the general trend, which aggregate values of the group and tolerate the unexplained factors related to each individual. Statistical sampling procedures and research design are used in order to control for such variability. All these kinds of control indicate one thing: there is a need to account for and explain the source of variability.

The individual, family, school, and community factors constitute what Bronfenbrenner (1989) has termed the “social address" of the individual. New statistical procedures have emerged to deal with this complex situation, such as structural equation model (SEM) and hierarchical linear modeling (HLM) were used to analyze data in a fashion that is more complex. HLM is used to analyze data on multilevel basis: Level 1 is the student and family variables, which are used as predictors- (within) - that predict certain educational outcome, in this study, math achievement. All these variables are nested within specific educational setup such as classes and schools (Level 2). An analysis of data is used to find whether the differences between school variables affect the educational outcomes at level 1.

When conducting a research on human behavior- such as student achievement- we should consider that it is a product of students’ psychological structure, home environment context, and school climate. Students in different schools achieve differently which necessitate an investigation of the variables that are responsible for that difference. Therefore, an analysis on student level (level 1) and school level (level 2) should be performed (Bryk and Raudenbush, 1992; Nezlek and Zyzniewski, 1998; Robert, 2004; and Atkins, 2005).

Personal variables

Personal variables such as the high school GPA have been widely investigated. Harackiewicz, Barron, Tauer, and Elliot (2002) found that prior high school performance is one of the variables that contribute to college achievement. Gender also has been highly investigated as a variable especially its relationship to achievement. The gender of the subject was found to correlate significantly with the reading level where female subject scored higher than male subjects (Pollyann, and Onwuegbuzie, 2001; Olszewski-Kubilius and Turner, 2002). Male subjects, on the other hand out performed female subjects’ 2:1 in mathematics. Trusty, Robinson, Palata, and Ng (2000) also provided evidence that the reading scores of female participants were a significant predictor of their chosen fields, whereas mathematics scores were the significant predictor of the fields chosen by male participants. McDermott, Mordell, and Stoltzfus (2001) indicated similar results.

Several studies revealed the significant role of student variables on achievement. For instance, McLean (1997) investigated attitudes toward learning with regard to their achievement and found that five attitudinal factors were significantly related to academic performance by distinguishing between the attitudes of high and low achievers. Students' attitudes may not only directly affect academic achievement, but also indirectly influence the effect of other variables, as well. Abu-Hilal (2000) found that the effect of attitudes passes through the level of aspiration. McLean (1997) and Abu-Hilal (2000) studies shared consensus with regard to the significance of attitudes in predicting achievement. House (1997) and Hassan (2002) further complemented the results of earlier studies, with the former proving that the students' initial attitude towards school was significantly related to academic performance, while the latter found that attitudes predicted their deep approach to learning.

Academic self-concept has also been investigated with regard to its relationship to academic achievement. Byrne (1984) recognized the motivational effect of academic self-concept on academic achievement, in which any change in the former, results in change in the latter. Marsh (1990) longitudinal study investigated the reciprocal relationship between academic self-concept and academic achievement and found that the student's present achievement was affected by his prior academic self-concept. On the other hand, Marsh and Yeung's (1997) findings revealed that prior academic achievement did affect subsequent academic self-concept, and likewise, prior academic self-concept affected subsequent achievement with prior achievement being the control.

Family variables

Family variables are a second to personal variables, to be investigating to determine its' affects on students' achievement. The family might be highly structured in raising their children, and enforcing "do's" and "don'ts," which Ho (1994) termed "cognitive conservatism," in contrast to a naturally developed child, who is at each stage of life is qualitatively different from the others (Huntsinger, Jose and Larson, 1998).

Parental involvement is reportedly used as an indicator of the relationship among family members. For instance, Tayler (1996) found a positive effect of strong kinship relation on parental involvement in schooling.

Grolnick, Benjet, Kurowski, and Apostoleris (1997) investigated three types of parental involvement - behavioral, cognitive, and personal. At the behavioral level, it was found that a mother's involvement increased with high socio-economic status (SES). Similarly, the cognitive involvement was predicted from the mother's SES. Yet this model could not identify the demographic variables, which could decisively predict parental involvement. Since each family has some strength and means which are generally used to enhance their children's success, yet a lot depends upon a family's demographic composition.

Seyfried and Chung (2002) investigated the implications of ethnic groups as a crucial factor, and found the European American families significantly contributed to their children's school outcome. Hill (2001) and Hill & Craft (2003) further corroborated these results. Equally significant was the effect of family income on parental involvement (Hill, 2001; Flouri and Buchanan, 2003; Englund, Luckner, Whaley and Egeland, 2004).

Schools by itself represent an integral body. Its demographic properties interact with each other to make it a source of effect on student achievement and total development. The effectiveness of the school to achieve its goal is controlled by the quality and harmony among its variables. Bulach and Malone (1994) indicated that a difference in students' achievement comes as result of better school climate (Erpelding, 1999 and Hirase, 2000). Teacher efficacy and teacher satisfaction as indicated by Bahamonde-Gunnell (2000) are closely linked to school climate. In addition, Bulach (2001) showed that teacher experience has a positive effect on his performance. Cotton (1996) investigated the role of school size and reached a conclusion that a small school provides better learning opportunity for its students. Moreover, it increases the opportunity for more activities and comparative curriculum for the students (Monk, 1987; Bates 1993). Eichenstein (1994) showed that students and teachers in a small school have better attitudes toward the school climate. However, Al-Nhar (1999) failed to support these results when he investigated the effects of school factors on achievement.

This study is interested in determining variables that predict students' achievement in mathematics. In alliance with the study objective, it is important to assess the effects of the school variables, based on the idea that each school has different learning environment, which make student in the same school more similar than students in other schools. Therefore, the purpose of this study was to answer these questions: 1) how much do 8th grade schools in the State of Kuwait vary in their mean mathematics achievement? 2) Which variable of level 1 predicts student achievement in mathematics? 3) Which variables in level 2 contribute to the magnitudes of the prediction (slope) of variables in level 1?

Methods

Participants

Participants in this study were 865 eight-graders at the State of Kuwait (52% females, 48% males) and their parents. Furthermore, a stratified sample of 37 schools (18 boys' schools, 19 girls' schools) together with their principals and mathematics teachers were involved in the study.

This sample was randomly stratified cluster according to the educational region and school types (male and female schools). Schools were stratified by educational region. Within each school, one class of eighth grade was randomly selected.

Procedures

After obtaining consent from the Ministry of Education to conduct the study, the principals of the selected schools were contacted and informed about the purpose of the study. A schedule was then made for testing the students at their schools. Thirty- seven researchers from the Ministry of Education were involved and trained to administer the battery of scales.

Teachers' and Principals' Questionnaires were administered at the same day of students' scales administrations. Parents' questionnaire was sent to parents with there children.

Instruments

The assessment battery of mathematics test, students' questionnaire, teachers' questionnaire, and schools' questionnaire were used for the purpose of this study. The following is a description of each scale:

1- Mathematics Achievement Test consisted of 50 questions. Each item was scored 1 if it is correct or zero if it is wrong. The internal consistency reliability for mathematics achievement test was .82.

2- Students' questionnaire is a 77 item self-report instrument designed to measure 13 different domains. These domains are: Demographic information, students' opinion of school, students' subjects & teachers preferences, homework, attitudes towards school, students' academic self concept, student perception of parents involvement, leisure time, students future orientation, teacher concern, achievement motivation, students' perception of teacher efficacy, and quality of school equipments.
3- Parents' Questionnaire is a 33 item self-report instrument designed to measure five different domains. These domains are demographic information, home culture, parents' opinion of school, parents' attitudes towards learning, and parents' involvement.
4- Teachers' Questionnaire is a 36 item self-report instrument designed to measure seven different domains. These domains are demographic information, teaching methods, teacher load, teacher opinion of load, effective school facilities, teacher efficacy, and teacher satisfaction.
5- Principals' Questionnaire is a 27 item self-report instrument designed to measure four different domains related to principals and schools. These domains are demographic information, school demographic, principal efficacy, and equipment availability.

All instruments were pilot tested and items of questionable performance during pilot testing were reevaluated and, in some cases, modified to improve their contribution to the total scales.

Results

The One-way ANOVA (Unconditional Model)

The one-way ANOVA model was first analyzed to provide preliminary information about how much variation in the mathematics achievement lies within and between schools, and the reliability value of each school's sample mean as an estimate of its true population mean. Table (1) indicates results from the One-way ANOVA model.

Table (1): Results from the One-way ANOVA model (Unconditional Model)

Fixed effect	Coefficient	se		
Average school mean for math achievement	19.22	.57		
Random Effect	Variance component	df	χ^2	p-value
Variance between schools (school mean)	10.10	36	259.12	.000
Variance within schools (level-1 effect)	37.19			

Table (1) fixed effect result indicates that the weighted least squares estimate for the grand-mean mathematics achievement for 8th grade students is 19.22 with a standard error of .57, and a 95% confidence interval of -[19.22 ± 1.96 (.57) = (18.10 – 20.34)]- plausible values range for the means.

Also the variance components in Table (1) indicate that there is a significant difference between schools mean [χ^2 = 259.12, p< .001]. The intraclass correlation, which represents the proportion of variance in math achievement between schools, was

$\hat{\rho} = \tau_{\circ\circ} / (\tau_{\circ\circ} + \sigma^2) = 10.10/ (10.10+37.19) = .21$, where $\tau_{\circ\circ}$ ~ school-level variance

This indicates that 21% of the variability in math achievement is due to differences between schools. An estimator of the reliability of the sample mean of .85 indicates that the sample means tend to be quite reliable as indicators of the true school means (true population means).

Schools factors and achievement

Variables such as school-gender, number of students in school, and teacher's satisfaction were considered as school-level model (level-2), so that each school's mean is now predicted by these variables of the school. In this case, the students-level model remains unchanged: students' math achievement scores are viewed as varying around their school means. Table (2) shows the effect of school-level model factors.

Table (2): Effects of School gender, number of students, and teacher satisfaction.

Fixed effect	Coefficient	se	t-Ratio	p-value
Model for school means INTERCEPT, $\gamma_{\circ\circ}$	21.02	.62	34.11	.000
School gender, $\gamma_{\circ 1}$	-3.60	.82	-4.42	.000
# of students in school, $\gamma_{\circ 2}$	-.010	.003	-2.91	.007
Teacher satisfaction, $\gamma_{\circ 3}$	.41	.21	1.95	.05
Random Effect	Variance component	df	χ^2	p-value
Variance between schools (school mean)	5.05	33	139.02	.000
Variance within schools (level-1 effect)	37.23			

Table (2) fixed effect result indicates that there is a negative significant association between school gender, number of students in school and mean math achievement [($\hat{\gamma}_{\circ 1}$ = -3.60, t = -4.42); ($\hat{\gamma}_{\circ 2}$ = -.010, t = -2.91)], which means that females' schools scored higher on math achievement compared to males' schools (21.02 & 17.42 for both females and males schools, respectively); also any addition of students in schools will decrease math achievement. Results of teacher satisfaction indicate that the relation between teacher satisfaction and math achievement is significant, and predict average math achievement. The statistics value of [χ^2 = 139.02, p < .000] indicates that there is a significant difference among school means math achievement remains to be explained.

By comparing the $\tau_{\circ\circ}$ estimates across the two models, the proportion of variance between schools explained by the model with school-gender and number of students in school is (10.10 – 5.05) / 10.10 = .50, which means that 50% of the true between school variance in math achievement was explained by school-gender (female vs. male schools), number of students in school, and teacher satisfaction.

After removing the effect of school-gender, number of students in school, and teacher satisfaction, the correlation between pairs of scores in the same school that had been .21 is reduced to a conditional intraclass correlation of .12 that measures the degree of dependence among observations within schools that are of the same gender. The conditionals reliability estimates was .75 which represent the reliability with which one can discriminate among schools that are identical on school-gender and it magnitudes is less than the reliability of the sample means, which was estimated in ANOVA model.

In summary, the results of between school variances show that even after controlling for school gender, number of students in school, and teacher satisfaction, schools still varied significantly in their average achievement levels.

Student's factors and Math Achievement

The analyses here consider students' factors and math achievement relationship within the 37 schools. Table (3) shows the relationship between student's variables (predictors) and Math achievement. Table (3) fixed effect provides that students prior- achievement and self-concept are significantly related to math achievement within schools.

By comparing the τ_{00} estimates across the two models, the proportion of variance explained at level-1 is (37.21-26.06) / 37.21 = .29, which means that adding students variables (prior-achievement, and self-concepts) as a predictors of math achievement reduced the within-school variance by 29%. In other word, this means that prior-achievement, and self-concepts account for about 29% of the student-level variance in the outcome.

Table (3): Effects of students' variables on math achievement.

Fixed effect	Coefficient	se	t-Ratio	p-value
Overall mean achievement	19.20	.56	34.33	.000
Mean prior-achievement	1.76	.26	6.68	.000
Mean attitude towards school-achievement slope	.19	.11	1.74	.09
Mean self concept achievement	.43	.08	6.04	.000
Mean SES- achievement slope	.08	.08	.97	.34
Random Effect	**Variance component**	**df**	χ^2	**p-value**
Variance between schools (school mean)	10.71	35	370.02	.000
Variance within schools (level-1 effect)	26.06			

Parents' factors and Math Achievement

The analyses here consider parents' factors and math achievement relationship within the 37 schools. Table (4) shows the relationship between parent's variables (predictors) and Math achievement. Table (4) fixed effect provides that none of parents variables significantly related to math achievement within schools.

Table (4): Effects of parents' variables on math achievement.

Fixed effect	Coefficient	se	t-Ratio	p-value
Overall mean achievement	19.22	.55	34.65	.000
Mean family size-achievement slope	.30	.31	.98	.33
Mean attitudes towards learning-achievement slope	.032	.08	.38	.71
Mean opinion of education-achievement slope	-.03	.15	-.20	.84
Mean parents' -achievement slope	.02	.13	.122	.90
Mean Facility-achievement slope	.16	.09	1.74	.09

Results of Table (4) show that the parent's variables do not account for any of the variability in Grade 8^{th} Math achievement at either the student or school levels, once the influence of student's variables has been controlled.

Principals-related variables

Principal-related variables include such as number of experience in educational field, number of experiences in administration, number of classes in the school, and availability of equipments in the school. Results of the effect of these variables are shown in Table (5).

Table (5): Effects of the principal-related variables on math achievement

Fixed effect	Coefficient	se	t-Ratio	p-value
Overall mean achievement	19.24	.50	38.60	.000
Principal experience-achievement	-.15	.09	-1.60	.12
Principal experience in administration-achievement	.11	.10	1.11	.28
Number of classes-achievement	-.08	.21	-.38	.71
School facilities-achievement	-.08	.26	-.29	.77

As is shown in Table (5), all principals' variables were not related to math achievement. These variables were not able to predict math achievement.

Discussion & Conclusion

The study used multilevel approach to determine the personal and contextual variables, which predict 8th grade students' achievement in mathematics in the State of Kuwait. It showed a significant difference between school means. This result opens the door for further analyses to explain those differences. It found that girls' schools, small schools, and school with highly satisfied teachers were contributing to mathematics achievement in their schools. This result was of no surprise because teaching girls is smoother for the teacher than boys, especially in a conservative society like Kuwait. In addition, teaching in small schools is more rewarding than teaching in big schools (Cotton, 1996). Thus, having more satisfied and gratified teacher is expected.

The other source of variability, which had been investigated, was the differences between students at the same school that were related to student and family variables. Prior- achievement and academic self-concept were found to have a meaningful prediction power for achievement in mathematics. Prior-achievement, in the first place, is an indicator of the total achieving ability of the student; therefore, it is wise to think that achievement in mathematics is a product and continuation of that ability. Academic self-concept is an indicator of what the student think of him/her self as achiever. It represents the motivational factor that intervene achievement.

The study managed to explain the sources of variability of achievement in mathematics by virtue of multilevel approach, yet further studies are needed to explain the differences between schools by selecting at least two classes within each school.

Finally, based on the present assessment of this study, decision makers should consider variables such as school-gender, academic self-concept, teacher satisfactions, and school size to enhance achievement in mathematics. In addition, those variables should be taken as major sources for the development of the curriculum.

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