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Multilevel Analysis Approach for Determining 8th Grade Mathematics Achievement in Kuwait

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Abstract

The purpose of this study was to determine the magnitude of the effects of student 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 stratified cluster sample of 37 intermediate schools together with their principals and mathematics teachers were involved in this study Also. a sample of 865 eight graders from these selected schools and their parents participated in this study. The assessment battery of mathematics test, and questionnaires for students, parents, teachers, and principals were used for data collection.

The findings of this study revealed that the variation within schools was 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 were more important than school-level variables.

Key words: Hierarchal Linear Model (HLM), mathematics achievement grades, eight graders students in Kuwait.

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التحصيل الخطي المتدرج في تحديد تحصيل الرياضيات لطلبة الصف الثامن بمدارس دولة الكويت

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الملخص

إن الهدف من هذه الدراسة هو تحديد قيمة تأثير متغيرات الطالب، والمدرسة في التنبؤ بالتحصيل العلمي في الرياضيات لطلاب الصف الثامن بمدارس الكويت، وذلك باستخدام استراتيجية النموذج الهرمي الخطي في تحليل بيانات هذه الدراسة Hierarchal Linear model (HLM). لقد تم اختيار عينة عنقودية طبقية عشوائية من ٣٧ مدرسة من مدارس الكويت، وشارك كل من معلمي الرياضيات، ومديري هذه المدارس في هذه الدراسة. كما شارك في هذه الدراسة عينة، قوامها ٨٦٥ من طلاب الصف الثامن من ٣٧ مدرسة، تم اختيارها مسبقا، وبمشاركة والديهم أيضا. ولقد تم استخدام بطارية من المقاييس هي: اختبار الرياضيات، واستمارة الطالب، و استمارة الوالدين، و استمارة المعلم، و استمارة مدير المدرسة؛ وذلك لجمع بيانات هذه الدراسة.

ولقد أشارت نتائج هذه الدراسة أن التباين داخل المدارس أكبر من التباين بين المدارس نفسها، مما يعني أن متغيرات الطالب، مثل التحصيل السابق، ومفهوم الذات في التنبؤ بالتحصيل العلمي بمادة الرياضيات أكثر أهمية، مقارنة بمتغيرات المدرسة.

الكلمات المفتاحية: النموذج الهرمي الخطي (HLM)، التحصيل العلمي في الرياضيات، طلاب الصف الثامن بمدارس الكويت.

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Introduction

Researchers in psychology and education have always been interested in determining inter and intra individuals differences to investigate causes- effects relationships and to know that the individual is the one who decides the outcome of the treatment. It is one's nature and the nature of the interaction among one's personal variables, on the one hand, and family and school factors, on the other hand, which decides how one receives, assimilates, reacts to the treatment, and produces the behavioral changes. Therefore, researchers should evaluate this sort of interactions when analyzing their research data. Such interactions create contextual environment where each individual has his/her own domain. Many studies, however, consider the general trend which aggregates values of the group and tolerates 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.

Personal variables such as the high school GPA have been widely investigated as a predictor of success in college. Harackiewicz, Barron, Tauer, and Elliot (2002) found that high school performance is one of the variables that contribute to college achievement. Gender has also been investigated, in terms of its relationship to achievement. The gender of the subject was found to correlate significantly with the reading level where female subjects scored higher than male subjects (Pollyann & Onwuegbuzie, 2001; Olszewski-Kubilius & Turner, 2002). Male subjects, on the other hand, outperformed female subjects 2:1 in mathematics. Trusty, Robinson, Palata, and Ng (2000) 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) reported similar results.

Several studies revealed the significant role of student variables on achievement. For instance, McLean (1997) investigated attitudes toward learning with regard to students' 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 affect directly academic achievement, but also influence indirectly the effect of other variables. 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 showing that students' initial attitude towards school was significantly related to academic performance and the latter revealing that attitudes predicted students deep approach to learning.

Academic self-concept has also been investigated in relation to academic achievement. Byrne (1984) recognized the motivational effect of academic self-concept on academic achievement in a way that changes in the former result in changes in the latter. Marsh (1990) investigated in a longitudinal study the reciprocal relationship between academic self-concept and academic achievement and found that students' present achievement was affected by their prior academic self-concept. In another study, Marsh and Yeung (1997) 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 are second to personal variables to investigate to determine their affects on students' achievement. The family might be highly structured in raising children and in enforcing "do's" and "don'ts" which Ho (1994) termed "cognitive conservatism". This in contrast to a naturally developed child who is at each stage in life is qualitatively different from the other (Huntsinger, Jose, & Larson, 1998).

Parental involvement is reportedly used as an indicator of the relationship

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among family members. For instance, Tayler (1996) found in a sample of children a positive effect of strong kinship relation on parental involvement in schooling and found that poor kinship relations caused psychological distress.

Grolnick, Benjet, Kurowski, and Apostoleris (1997) investigated three types of parental involvement: behavioral, cognitive, and personal. Authors found at the behavioral level that a mother's involvement increased with high socio-economic status (SES). They also found that the cognitive involvement was predicted from the mother's SES. Yet this model could not identify the demographic variables that could decisively predict parental involvement. Because family has some strengths and means that are generally used to enhance their children's success, 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 that European American families contributed significantly to their children's school outcomes. Hill (2001) and Hill and Craft (2003) corroborated these results. Equally significant was the effect of family income on parental involvement (Hill, 2001; Flouri & Buchanan, 2003; Englund, Luckner, Whaley, & Egeland, 2004).

A school by itself represents an integral body. Its demographic properties interact with each other to make it a source of effect on students' achievement and total development. The effectiveness of school to achieve its goals is controlled by the quality and harmony among its variables. Bulach and Malone (1994) indicated that a difference in students' achievement comes as a result of a better school climate (Erpelding, 1999; Hirase, 2000). Teacher efficacy and teacher satisfaction as indicated by Bahamonde-Gunnell (2000) are closely linked to the school climate. Bulach (2001) showed that a teacher's experience has a positive effect on his/her performance. Cotton (1996) investigated the role of school size and reached a conclusion that a small school provides a better learning opportunity for students. Moreover, it increases the opportunity for more activities and comparative curriculum (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) did not support these results when investigated the effects of some school factors on achievements.

Purpose of the Study

This study was conducted to determine the variables that predicted students' achievement in mathematics. In line with the study objective, it is important to assess the effects of school variables based on the idea that each school has a different learning environment that makes students in one school very similar to students in another. Figure (1) represents a diagram of structural equation model illustrating proposed factors influencing students' mathematics achievement.

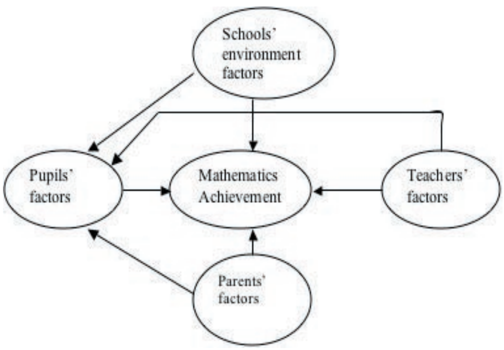

Figure (1): Diagram of structural equation model illustrating proposed factors influencing Mathematics Achievement

Research Questions

The study attempts to answer these questions by using methods of hierarchical linear modeling (HLM):

1) How much do 8th grade schools in the State of Kuwait vary in their mathematics achievement?

2) Which variables of students' factors (in level 1) predicts students' achievement in mathematics?

3) Which variables of schools' factors (in level 2) contribute to the magnitudes of the prediction of students' variables in level 1?

Significance of the Study

The project of "Educational Indicators and National Capacity Building in Kuwait" (Al- Sarraf, Morad, Al-Omar, & Hadi, 2004) was a pioneer endeavor in the State of Kuwait. It was the first comprehensive attempt to evaluate the outcomes of intermediate school stage not only by measuring educational achievements but also by studying the inputs and processes that influence educational outcomes in order to specify the educational indices involved in quality of education.

It was noticed in this project that students' grades in mathematics were low compared to other subject matters. It was also noticed that students' grades in mathematics and physics were low at the secondary school level, indicating that the low performance in mathematics achievement continued from intermediate stage to the secondary stage. Therefore, the researchers of this study decided to conduct in depth study to identify the causes leading to low school performance in mathematics among intermediate school students (i.e., the eighth grade which is the last year in intermediatemiddle school) and to determine the indices which could help in developing the educational process in the area of mathematics in the State of Kuwait.

Limitations of the study

The limitations of this study were manifested in the following points:

1- A sample of eighth grade male and female students (the last year of intermediate school) in the year 2002/2003 enrolled in schools in the State of Kuwait.

2- School achievement grades in mathematics for eighth grade students.

3- The result of this study was determined by the instruments validity and reliability estimates.

Methods and Procedures

Participants

A sample of 37 schools (18 boys' schools and 19 girls' schools) was randomly selected from a population of 146 Intermedate schools (70 were males' schools and 76 were females' schools). This sample formed 25% of all intermediary schools. The schools sample was randomly stratified cluster according to the six Educational region in Kuwait (i.e, Asma, Hawally, Farwania, Mubarak Al-Kabeer, Ahmedi, and Jahra) and school types (male vs. female schools). Within each school one class of eighth grade was randomly selected. The students of each chosen class were participated in this study. The participants were 865 eight-graders (52% females and 48% males) together with their parents (865 parents). Thirty-seven mathematics teacher and principals of the chosen schools were also involved in this study.

Procedures

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

Questionnaires for teachers and principals were administered on the same day of students' scales administrations. Parents' questionnaire was sent home with their children in order to be answered by either one of the parents.

Instruments

The assessment battery of mathematics test, students' questionnaire, teachers' questionnaire, and principals' questionnaire were used in this study. The following was a description of each scale:

1- Mathematics Achievement Test consisted of 50 multiple-choice items with four alternatives. Each item was scored 1 if it is correct or 0 if it is wrong. A committee of six experts in the field of mathematics and measurement judged the content validity of the test according to the table of specification. The internal consistency reliability for mathematics achievement test was .82 using Cronbach alpha procedure.

2- Students' questionnaire consisted of 77 items of self-reporting instrument designed to measure 14 different domains. These domains were demographic information, students' opinion of school, students' subjects & teachers' preferences, homework, attitudes towards school, students' academic self-concept, students' perception of parents involvement, students' future orientation, teacher concern, achievement, motivation, students' perception of teacher efficacy, and quality of school equipments. Reliability estimate of Cronbach alpha was .89.

3- Parents' Questionnaire consisted of 33 items of self-reporting 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. Internal consistency reliability using Cronbach alpha was .81.

4- Teachers' Questionnaire consisted of 36 items of self-reporting instrument designed to measure seven different domains. These domains were demographic information, teaching methods, teacher load, and teacher opinion of load, effective school facilities, teacher efficacy, and teacher satisfaction. Reliability estimate for this scale using Cronbach alpha was .73, which is acceptable for the purpose of this study.

5- Principals' Questionnaire consisted of 27 items of self-reporting instrument designed to measure four different domains related to principals and schools. These domains are demographic information, school demographic, principal efficacy, and equipment availability. Internal consistency reliability Cronbach alpha was .70, which is considered acceptable for this study.

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. All questionnaires were reviewed by the experts and specialists in the field of measurement; and based on their comments changes were made in some domains of the questionnaires. Demographic information in all questionnaires was not considered in estimating reliabilities. For more details regarding item analyses and validity indications by estimating correlations among all scales variables, readers could refer to the full report of Educational Indicators and Capacity Building: Phase II (Al-Sarraf et al, 2004).

Data Analysis

The data of this study was analyzed using methods of multilevel and hierarchical linear modeling (HLM). The advantage of multilevel modeling over simple regression or ANOVA is that it allows the researcher to look hierarchically at data structures and interpret results in terms of these structures. This is accomplished in multilevel modeling (MLM) by including a complex random part that can appropriately account for correlations among the data variables (Robert, 2004).

A multilevel or hierarchically structured dataset can take many forms. All what required is level-1 units of some type (in our case, students) be nested inside level-2 units (in our case, schools). Although the two-level structure is the most common, multilevel models are not restricted to just two levels; they simply must have at least two levels (Raudenbush & Bryk, 2002). Roberts (2004) pointed out that neglecting the fact that individuals or measurement occasions may be nested inside other larger clusters will often lead researchers to erroneous conclusions about their data. In a sense, multilevel analysis combines the strengths of regression and ANCOVA designs by allowing researchers to predict outcome scores along with other continuous or non- continuous variables while taking into account the fact that the scores may be nested within groups. Hence, researchers are able not only to determine which schools differ but examine why they differ (Roberts, 2004).

In a multilevel modeling, the procedure is not that simple. We must first built a null or baseline model against which to compare future models; then we enter each variable one at a time to see the unique contribution that each variable presents or fails to present to the total model. A variety of statistical computing programs are available for fitting these models including HLM, MIXOR, MLWIN, AND SAS PROC MIXED. In our study, HLM (Roberts, 2004) was used to analyze the data.

Results

The One-way ANOVA (Unconditional Model)

One-way ANOVA model was first conducted using HLM program to provide preliminary information on 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	Standard error (se)		
Average school mean for math achievement	19.22	.57		
Random Effect	Variance component	df	χ^2	p-value
Variance between schools	10.10	36	259.12	.000
Variance within schools	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 (18.10 – 20.34) as plausible range values for the means indicating a substantial range in average achievement levels among schools in data.

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 $\hat{\rho} = \tau_{00} / (T_{00} + \sigma^2) = 10.10/ (10.10+37.19) = .21$, where τ_{00} ~ 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 teachers satisfaction were considered school-level model (level-2) to predict school's mean. 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, γ_{00}	21.02	.62	34.11	.000
School gender, γ_{01}	-3.60	.82	-4.42	.000
# of students in school, γ_{02}	-.010	.003	-2.91	.007
Teacher satisfaction, γ_{03}	.41	.21	1.95	.05
Random Effect	Variance component	df	χ^2	p-value
Variance between schools	5.05	33	139.02	.000
Variance within schools	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 [($\hat{Y}_{01}$ = -3.60, t = -4.42); ($\hat{Y}_{02}$ = -.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 classes within 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 [$\chi^2 = 139.02$, $p < .000$] indicates that a significant difference among school means math achievement remains to be explained.

By comparing the τ_{00} 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), the number of students in school, and teacher satisfaction.

After removing the effect of school-gender, the 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 of the same gender. The conditionals reliability estimates was .75 representing the reliability with which one can discriminate among schools that are identical on school-gender and its magnitude of less than the reliability of the sample means, which was estimated in ANOVA model. The results of between school variances show that even after controlling for school gender, the number of students in school, and teacher satisfaction, schools still varied significantly in their average achievement levels.

Student's Factors and Math Achievement

The analysis 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	10.71	35	370.02	.000
Variance within schools	26.06			

Parents' Factors and Math Achievement

The analysis 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 the 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 8th Math achievement at either the student or school levels once controlling the influence of student's variables.

Principals-related Variables

Principal-related variables include number of experience in educational field, administration, number of classes, 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 shown in Table (5), all principals' variables have not been related to maths achievement. This indicates that these variables were not able to predict maths achievement at student or school levels while controlling for students variables.

Discussion and Conclusion

This study used multilevel approach to determine the personal and contextual variables that could predict 8th grade students' achievement in mathematics in the State of Kuwait. The results have shown a significant difference between school means, which opens the door for further analyses to explain these differences. It has been found that girls' schools, small schools, and schools with highly satisfied teachers were contributing to high mathematics achievement. This result was of no surprise because teaching girls is smoother for teachers than teaching boys, especially in a conservative society like Kuwait. Historically, it has been proven that girls outperformed boys in national examinations at high school levels across all areas of study. Therefore, it is not surprising to excel in mathematics as well. This could be due to level of motivation to pursue their higher education because they have limited opportunities beyond the high school diploma. Furthermore, girls have more time to study compared to boys because they stayed home most of the time. In addition, teaching in small schools is more rewarding than teaching in big schools (Cotton, 1996), thus, having more satisfied and gratified teachers.

The other source of variability, which has been investigated, was differences between students at the same school that have been related to student and family variables. This study found that family variables (e.g., family size, attitudes and opinions towards learning, and facilitating learning) have no significant influence on mathematics achievement. This contradicts with results from pervious research which indicated that family involvements in the education of their children influenced directly school performances in various subject matters (Englund et al, 2004, Grolnik et al., 1997, Hill & Craft, 2003). The results of this current study indicate that family may not have taken an active role in children's education and in cooperation with schools except when there is a behavioral problem which requires a parent, usually the mother, be present in school. It is to mention that the mother in the Kuwaiti society is the one who looks after children on a daily bases and due to number of family members, her effort is meager and insignificant in the education of her children.

Prior achievement and academic self-concept were found to have a meaningful prediction power for mathematics achievement. Prior achievement, in the first place, is an indicator of the total achievement ability of the student. Therefore, it is wise to think that achievement in mathematics is a product and continuation of that ability. These results are similar to Harackiewicz et al (2002) and Marsh & Yeung (1997) where self- concept and prior achievement are predicting academic achievement. Academic self-concept is an indicator of what the student thinks of him/herself as achiever. It represents the motivational factor that intervenes achievement. This result is consistent with Marsh (1990) study where self-concept indicated as a variable that facilitated academic achievement.

This study managed to explain the sources of variability of achievement in mathematics by virtue of multilevel approach. Yet further studies are needed to explain differences between schools by selecting at least two classes within each school. In addition, some students' factors need to be investigated such as student's interests in mathematics, academic self-concept in mathematics, and student's efficacy in mathematics. These variables have not been studied here because they were the prime focus of the original study since it aimed at the study of the educational indicators of students' achievement. On school level, a study could be done on the ministry's special effort to promote the study of mathematics and how can this be realized in classrooms.

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, these variables should be taken as major sources for curriculum development.

This study did not show significant influences for the school variables on mathematics achievement. This was attributed probably to similarities among schools in terms of available resources, the number of classrooms per school, the experiences of school principals, and the degree of making the learning process feasible in these schools. It seems that school teaching does not facilitate the learning process in a way that appropriate resources and technologies are not being used. This is apparent in the significant low performance in mathematics grades (the average is equivalent to 32%) where achievement in mathematics requires high degree of deductive and inductive thinking and demands that teachers develop and enhance these thinking skills through utilizing more updated educational resources. The low performance in mathematics may also be attributed to the students' indifference to respond correctly to a test, the result of which will be used for research purposes and not for school grades. It could also be possible that differences are attributed to the distinct characteristics of male and female schools in which females outperformed males, contradicting previous research which reported that males outperformed females in mathematics.

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