Comparing the Low- and High-Performing Schools based on the TIMSS in the United States

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Abstract

Because school difference has been shown to be one of the determinants of students' science performances, this study was carried out to investigate the differences between low- and high-performing schools in the United States based on TIMSS 2007. Discriminant analysis was conducted to explore the differences between low- and high-performing schools. The results revealed that the classified schools were significantly discriminated based on the six composite variables. Whereas using of inquiry-oriented activities were found to be encouraged in high-performing schools, teacher-centered activities were more often implemented in low-performing schools. As expected, socioeconomic status (SES) of the students was found to be one of the critical factors that explain the extent of variation of students' science performances should be considered intensively by school administrations.

Keywords: TIMSS, school effectiveness, science achievement, discriminant analysis

Introduction

With their importance for education and having fruitful data, international studies such as TIMSS (Trends in Mathematics and Science Study), PISA (Programme for International Student Assessment), and PIRLS (Progress in International Reading Literacy Study) have drawn attention of many researchers all around the world. Without a doubt, TIMSS (Trends in Mathematics and Science Study) is one of the most well known and largest comparative education studies to assess students' science and mathematics achievements in line with the school curricular context in different countries, have been carried out once every four years. Approximately half of a million of students at fourth and eighth grade levels from 59 countries involved in TIMSS-2007 (Martin, Mullis & Foy, 2008).

To understand whether school difference significantly impacts students' academic achievement is essential to ensure equity across schools. To what extent the variation in the science performance of different students is associated with students attending different schools is one of the concerns of these international studies. For example, PISA 2006 reports revealed that although the results varied widely from one country to another, one third of all variation in students' performance was between schools (OECD, 2007). In addition, the importance of schools was also expressed by the results of TIMSS (Schmidt, Jorde, Barrier, Gonzala, Moser, & Shimizu, 1996). Moreover, a meta-analyses study which was conducted based on 103 school effectiveness study revealed that almost 18% of variance in achievement associated with school difference (Bosker & Witziers, 1996). Therefore, it would be meritorious to pursue of revealing the attributes that make specific schools efficient.

Beside the school characteristics, Nolen (2003) revealed that classroom characteristics also affect students' achievement more than the motivational characteristics. In addition, Odom, Stoddard, and LaNasa (2007) concluded that classroom teaching practices are another crucial factors influencing students' science achievement. Moreover, student-centered activities and students' attitudes towards science which were stated as one of the significant predicators of science achievement were found

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positively correlated with each other (Papanastasiou, Zembylas, & Vrasidas, 2004). Furthermore, there are lots of researches that investigate the relationships among the aforementioned variables with regard to international studies data sets (Atar & Atar, 2012; Aypay, Erdogan, & Sozer, 2007; Papanastasiou, 2008; Papanastasiou, Zembylas, & Vrasidas, 2004; Papanastasiou & Papanastasiou, 2004; Yayan & Berberoglu, 2004).

On the other hand, students' socioeconomic status (SES) and educational background of their families were stated as some of the relevant factors with the school performance (Papanastasiou, 2008). Although the researchers define socioeconomic status in different ways, the robust relationships between SES and test scores was well replicated in the social sciences (Konstantopoulos, 2006; White, Reynolds, Thomas, & Gitzlaff, 1993).

Not only the overall science scores of the students, but also three different scores such knowing, applying, and reasoning scores of the students were produced based on the related questions for the cognitive dimensions in TIMSS. The nature of the reasoning questions in TIMSS would give us an opportunity to use them for interpreting students' views of nature of science and their procedural knowledge. In addition, students' science scores and their reasoning scores are strongly correlated to each other for the US eighth grade students in TIMSS 2007. Therefore, in the light of the school effectiveness research and the investigations based on international studies, low-performing schools and high-performing schools in the United States were compared with respect students' science reasoning scores based on some variables in TIMSS-2007. The composite variables such as students' attitude towards science, inquiry-oriented activities, necessity to learning science, teacher-centered activities, out of school activities, and students' socioeconomic status which were extracted from the factor analysis of student questionnaire were the focus during the investigation of differences between low- and high-performing schools.

Methods

Sample

As a result of two stage stratified cluster sampling used in TIMSS (Gonzales & Miles, 2001; Joncas, 2007; Martin, Gregor, & Stemler, 2000), 7377 students from 239 schools, included both private and public schools, were sampled at eighth grade level in United States. This sample consisted of 3721 girls and 3656 boys. For the present study, 48 schools, included 1465 students, were included. 24 of these schools were named as low-performing schools and 24 of the schools were named as high-performing schools as a result of their students' science reasoning scores in TIMSS-2007. These schools included 783 boys and 682 girls. The number of the students in low performing schools and high performing schools were 753 and 712, respectively.

Instruments

TIMSS-2007 Student Questionnaire were applied to delineate students' background characteristics, their self concepts, their science attitudes, science teaching practices in the classrooms, their out of school activities, and their homework habits (Martin et al., 2008). In addition, TIMSS-2007 Science Achievement Test was applied to gather information about students' performance with regard to science curricular aspects. Science Achievement Test included 94 science items from Biology, Chemistry, Physics, and Earth Science content domains. Besides these content domains, this test composed of three different cognitive domains stated as knowing, applying, and reasoning. Students' science reasoning scores were used this study to make some inference about students' higher order thinking skills and their views about nature of science.

Analysis

Discriminant analysis is used to classify individuals into groups on the basis of one or more measures or realize the group differences (Green, Salkind, & Akey, 2000). Discriminant analysis was conducted based on six factor structures (students socioeconomic status, their attitude toward science, classroom activities, students' out of school activities) included 30 variables (items) from the students responses of student questionnaire.

Before conducting the discriminant analysis, all of the schools (239) in the United States were ranked from highest to lowest based on their mean values on science reasoning scores. Ten percent of the highest performing schools (24 schools at the top of the list) and 10% of the lowest performing schools (24 schools at the bottom of the school list) were taken for both discriminant analyses. Cases of the other schools were considered as moderately performing schools and excluded from the data set. So, our sample included 48 schools included with 1465 students. Students' average scores for low-performing schools was 435.62 and average score of the high-performing schools' students was computed as 592.95.

In the discriminant analysis the stepwise procedure was selected. Wilks' lambda was minimized at each step by adjusting F-to-enter as 1.15 and F-to-remove as 1.00. In addition, Box's M was clicked to check multivariate normality. To understand the multivariate nature of independent variables the univariate analysis of variance was selected. Furthermore, unstandarized discriminant function coefficient, the combined groups plot, residual for each case, and summary table were ticked (Green, Salkind, & Akey, 2000).

Results

As mentioned earlier, discriminant analysis was performed to understand whether there are differences between low-performing schools and high-performing schools with regard to some of the constructs extracted by the factor analysis of some items in student questionnaire. Therefore, before the discriminant analysis, principle component analysis was performed to derive the factors based on selected items from the student questionnaire.

Principle Component Analysis

Principle Component Analysis were conducted with using some of the items related to students' background characteristics, their self concepts, their science attitudes, science teaching practices in the classrooms, students' out of school activities, and their homework habits from the questionnaire to gather the factor scores. 30 variables (items) were selected to determine and confirm the dimensions. Some of the studies in the literature were taken into consideration in the process of selection of these items (Apay, Erdogan, and Sozer, 2007; Ceylan & Berberoglu, 2007; Papanastasiou, 2002 Yayan & Berberoglu, 2004).

Some of the indexes were examined to check the assumptions of principle component analysis. 0.863 was found as an index of KMO value. This means that the distribution of the data of selected items was meritoriously sufficient enough to run the principle component analysis. In addition, as a result of Barlett's test of sphericity a significant value ($p < 0.05$) was obtained. It can be said that the assumption of multivariate normality was ensured (George & Mallery, 2006).

Six factors with the eigenvalues of 6.09, 3.33, 2.09, 2.03, 1.70, and 1.52 were gathered as a result of the factor analysis for the advance analysis. Explained variance for each factor was found to be 20.30%, 11.10%, 6.97%, 6.77%, 5.69%, and 5.07% were gathered, respectively. In addition, the Scree Test confirmed the results by delineating the six plots in the sharp descent and the other plots began to level off. Table 1 represents the constructs as a result of the principle component analysis, the names of the related factors, and their respective factor loadings. Items which have a value of 0.40 and lower factor loading were not included in the table. Total explained variance is 55.9% with the six factors in the present study.

Table 1.
Factor Structures, Factor Names, and Factor Loadings for Factor Anlaysis

ITEMS	FACTOR NAMES	F1	F2	F3	F4	F5	F6
1.Science as one of her/his strength	**Attitude toward science**	**.753**					
2.Doing well in science		**.735**					
3.Learning things quickly in science		**.727**					
4.Difficult for me than for many of my classmates (reversed)		**.724**					
5.Degree of liking science		**.698**					
6.Enjoying learning science		**.663**					
7.Science is boring (reversed)		**.626**					
8.Conduct an experiment or investigation	Inquiry-oriented activities		.833				
9.Teacher demonstrates an experiment or investigation			.797				
10.Design or plan an experiment or investigation			.792				
11.Make observations and describe what is seeing			.730				
12.Work in small groups on an experiment or investigation			.708				
13.Need to do well in science to get a job	**Necessity to learning science**			**.782**			
14.Need science to learn other school subjects				**.755**			
15.Need to do well in science to get into the university				**.749**			
16.Learning science will help me in my daily life				**.747**			
17.Memorize science facts and principles	Teacher-centered activities				.660		
18.Read the textbook and other source materials					.657		
19.Work problems on their own					.652		
20.Have a quiz or test					.611		
21.Use scientific formulas and laws to solve problems					.594		
22.Teacher give a lecture style presentation					.575		
23.Use internet before or after the school	**Out of school activities**					**.769**	
24.Play computer games before or after the school						**.710**	
25.Watch TV and videos before or after the school						**.669**	
26.Play or talk with friends before or after the school						**.610**	
27.Home possesses internet connection	Socioeconomic status						.807
28.Home possesses computer							.749
29.Number of books at home							.605
30.Home possesses study desk							.438

Factor analysis results indicate that first factor (attitude towards science) composed of seven variables, second factor (inquiry-oriented activities) composed of five variables, third factor (necessity to learning science) composed of four variables, fourth factor (teacher-centered activities) composed of six variables, fifth factor (out of school activities) composed of four variables, sixth factor (socioeconomic status) composed of four variables. Some related literature (Atar & Atar, 2012; Aypay, Erdogan, and Sozer, 2007; Ceylan & Berberoglu, 2007) and the characteristics of the items item that loaded on the same construct were taken into consideration in the process of assigning the names of factors.

Discriminant Analysis

Discriminant analysis was performed based on factor scores that were extracted from the factor analysis. Six factor scores were derived from the factor analysis. Dependent variable of the study, classified as low- and high-performing schools based on students' science reasoning scores, was defined as school performance. The independent variables were the factor scores of related constructs (attitude toward science, inquiry oriented activities, necessity to learning science, teacher centered activities, out of school activities, and socioeconomic status). Box's test was used to understand whether the assumption of the equality of the covariance matrices (multivariate normality) was violated. Although the test result was found significant meaning the assumption of multivariate normality was not met, discriminant analysis yields valid results with moderate to large sample size (Green, Salkind, & Akey, 2000).

The eigenvalue and the canonical correlation of the discriminant analysis were found 0.629 and 0.620, respectively. Since the larger eigenvalue indicates better discrimination, it can be said that this eigenvalue imply a strong function. Moreover, a high correlation implied the function discriminate well. The accounted variance in the dependent variable is understood by the square root of canonical correlation. The eta square, square root of canonical correlation was found 0.384, indicates that 38% variability of scores for the discriminant function was accounted for by the difference among the two groups of schools. On the other hand, Wilks' lambda and chi-square values are used to assess whether the groups significantly differ from each other based o the discriminant function. Wilk's lambda was found 0.615. The discriminant function had X^2 (6, N = 1465) = 636.3, and $p < 0.05$. These values indicated that there were significant differences between high- and low-performing schools based on six composite variables at 0.05 level of significance. Table 2 presents these results.

Table 2.
Summary the Canonical Discriminant Function

Function	Eigenvalue	% of Variance	Canonical Correlation	Wilks' Lambda	X^2	df	Significance
1	0.626	100	0.620	0.615	636.303	6	0.000

Table 3 represents the standardized correlation and correlation coefficient for six factor scores in the discriminant function. The discriminant function which was based on six factor scores can be written according to Table 3 as:

DF = 0.915 (SES) + 0.311 (ATS) + 0.193 (IOS) + 0.48 (NLS) – 0.113 (TCA) – 538 (OSA)

Table 3.
Standardized canonical discriminant function and canonical discriminant function coefficients

FACTORS	Standardized Canonical Discriminant Function Coefficients	Canonical Discriminant Function Coefficients
Socioeconomic Status (SES)	.915	1.066
Attitude toward Science (ATS)	.311	.318
Inquiry Oriented Activities (IOS)	.193	.193
Necessity to Learning Science (NLS)	.048	.049
Teacher-Centered Activities (TCS)	-.113	-.113
Out of School Activities (OSA)	-.538	-.564
Constant		-.006

Which independent variables differed significantly in discriminating the high- and low performing schools can be understood by the relative positions of the categorized schools indicated by group centroids (Table 4). These centroids indicates, in the function, positively valued independent variables were for high performing schools and negatively valued independent variables were for the low performing schools. Also, the group centroids indicate the average discriminant scores for subjects in high- and low-performing schools (George and Mallery, 2006).

Table 4.
Functions at Group Centroids

School Category	Discriminant Function 1 (DF1)
Low Performing Schools	-0.776
High Performing Schools	0.805

The factor structures that students have high factor scores in high-performing schools can be categorized as: Socioeconomic status, Inquiry-Oriented Activities, Attitude toward Science, and Necessity to Learning Science. On the other hand, the composite variables that student have high factor scores in low- performing schools can be categorized as: Teacher-Centered Activities, Out of School Activities. In other words, it can be inferred that students in the high performing schools tended to have high socioeconomic status, do more inquiry activities in their science classes, have positive attitudes toward science, and understand that learning science is a necessity for them. On the other hand, students in the low performing schools tended to do more teacher centered activities in their science classes, and spend more time on out of school activities.

The classification results of the discriminant analysis indicate that the percentage of correctly classified students in low- and high-performing schools were 75.2% and 86.4%, respectively. In addition, 80.7% of the students in the sample (1465 students) were correctly classified which indicate good classification results. In addition, students' science reasoning scores were influenced in high performing schools by: students' socioeconomic status ($\beta = 0.915$), students' attitude toward science ($\beta = 0.311$), inquiry oriented activities in science classrooms ($\beta = 0.193$), necessity to learning science ($\beta = 0.048$). On the other hand students' science reasoning scores were influenced in low performing schools by: teacher centered activities in science classroom ($\beta = -0.113$) and out of school activities ($\beta=-0.538$).

Based on the results of discriminant analysis it can be argued that students who performed more student-centered activities or inquiry oriented activities had better science reasoning scores on the TIMSS science test than students who used teacher-centered activities more. In addition, discriminant analysis revealed that students who had high reasoning scores had positive attitudes toward science, their socioeconomic status was higher and they spend less time in out of school activities. The results and their reasons will be discussed further in the section below.

Discussion and Conclusion

The purpose of the study was to investigate the differences between low- and high-performing schools based on selected composite variables such as students' socioeconomic status, their attitude toward science, teacher-centered activities, inquiry-oriented activities, understanding of the necessity to learn science, and out of school activities. The schools were classified as low- and high performing school based on students' reasoning scores in TIMSS-2007. Discriminant analysis was conducted with regard to these composite variables that were extracted by using factor analysis of TIMSS-2007 student questionnaire. Discriminant analysis results showed that low-performing schools differs from high performing schools with regard to the six composite variables based on TIMSS-2007 data for eight grade students in the United States.

When the factor scores (mean of factor scores) of the students based on the factor analysis are examined, it is seen that whereas factor scores of socioeconomic status, attitude toward science, inquiry oriented activities, and the understanding of the necessity to learn science are higher in high-performing school, factor scores of teacher-centered activities and out of school activities are higher in low-performing schools. In other words, students' socioeconomic status and students' attitude toward science are high in high-performing schools. In addition, inquiry-oriented activities were more implemented in science classes in high-performing schools and students in high performing schools thought about science as a necessary subject for their life. On the other hand, teacher -centered activities were more implemented in science classes in low-performing schools and students in low performing schools spend more time for out of school activities.

Studies expressed the substantial relationship between socioeconomic status and students' academic achievement (e.g. Gustafsson, 1998; Yang, 2003). However, treating SES as a one-dimensional concept may hide the effects of different dimensions of SES on students' academic achievement. Parents' education level, students' educational resources, household possessions, quality of learning environment can be stated some of the dimensions of SES and generally used as an indicator of SES (Konstantopoulos, 2006). In this study, household possessions were used as indicator of SES. In addition, it was revealed that there was a strong relationship between student level SES and students' science achievement based on Estonian TIMSS-2003 data (Mere, Reiska, and Smith, 2006). Therefore, finding high socioeconomic status as one of the characteristic of students in high-performing schools shows a consistency with the previous research.

One of the results of the present study is the positive contribution of students' attitude toward science composite variable on students' science reasoning scores. In other words, students in high performing school have tendency of having positive attitude toward science. A great deal of studies has been carried out to investigate the nature of the mutual relationship between students' attitude and their achievement (Atar & Atar, 2012; Ceylan & Beberoğlu, 2007; Aypay, Erdogan, and Sozer, 2007) . Gibson and Chase (2002) revealed that activities that were actively engaging in science using a hands on inquiry based approach helped middle schools students to maintain their interest during their years in high school. In other words, use of the inquiry based approach resulted in sustaining students' high interest in science. In the current study, besides having students with high attitudes toward science, one of important characteristics of high-performing schools found was implementing more inquiry based activities in their science classrooms. Therefore, besides students' high science reasoning scores in high-performing schools, one of the reasons of students' high attitude towards science may be the implemented instructional practices in science classrooms in these schools.

As a result of the present study, the factor of "inquiry-oriented activities" positively contributed to students' science reasoning scores. Namely, inquiry-oriented activities were implemented more in the science classrooms of high performing schools. Those activities which constitute the factor of inquiry-oriented activities are: conducting experiment and investigation, demonstrating an experiment and investigation by teacher, designing and planning an experiment and investigation, making observations, working in small groups on an experiment and investigation. In a study conducted in Japan which had scores above the international averages on science achievement revealed eight specific activity structures observed in science lessons in Japan. Designing experiments by teachers, conducting experiments by students, sharing the results of these investigations, and discussing the investigations in small groups were stated as some of these activities (Linn, Lewis, Tsuchida, & Songer, 2000). In addition, students in Chinese Taipei who engaged more in the activities related to conducting experiments and investigations had a tendency to acquire high science test scores (House, 2007, 2008). As stated earlier, several studies which presented the substantial theoretical and empirical evidence of inquiry-based instruction that leads higher achievement of all students have been carried out (Stright & Supplee, 2002; Von Secker & Lissitz, 2002). In addition, Von Secker (2002) argued that although greater emphasis on inquiry-based teaching leads to greater science achievement, improper and sloppy usage of these activities may encourage the gap to widen among students. On the other hand, some of the studies that were conducted in Turkey indicated the negative relationship between student-centered activities and students' science achievement based on TIMSS data (Aypay, Erdogan, & Sozer, 2007, Ceylan & Berberoglu, 2007). However, one of the reasons of this result in Turkey may be the improper implementation of these activities in science classes. In the current study, it can be said from the results that the more often students were exposed to the inquiry-based activities, the greater their science reasoning scores and their science achievement in United States.

The factor of "out of school activities" found as a one of the characteristics of low-performing schools. In other word, results revealed that as eighth grade students in US spend more time in outside-curriculum related activities that constitute this factor, they are likely to be less successful in the science reasoning measures of the TIMSS. This might be the impact of very intense and bulky curricular content of the science education at eight grade level. It could also mean they are not spending enough time exploring science in their curriculum, or that kind of curriculum available in the low performing schools does not overshadow the outside-curriculum activities in which the students engage.

In the light of the results of this study, implementing inquiry-oriented instruction properly in the science classrooms is strongly recommended. Implementation of this kind of proper instruction may help to decrease the gap between two types of schools. During the textbook adoption period, inquiry-based activities should be placed in the curricula and in-service training programs should be provided for science teachers to implement such an instruction more effectively. Low-performing schools which are located in the low SES districts should be supported with regard to the enrichment of their materials and science classrooms settings.

The schools which were grouped as low- and high-performing schools in this study cannot be compared and contrasted with regard to their resources since the schools' names and their proveniences were not revealed by the TIMSS. However, as the other studies in the literature indicated (Von Secker & Lissitz, 2002), providing equal opportunities in terms of laboratory facilities, equipment, and supplies to both types of schools are likely narrow the gaps among these schools. Beside these, teachers who are specially qualified to teach specific science topics, such as physics are not deployed in schools which are located in low SES areas. Moreover, diverse science content courses cannot be offered due to low enrollments, lack of materials, or difficulty in finding instructors in some lower SES schools which are located in the rural areas. We can say that education opportunities are not equal at U.S. schools based on the results of this study.

Finally, analysis of the TIMSS-2007 U.S. data set revealed the prominent differences between low- and high-performing schools. These differences arise very likely from the students' socioeconomic status, classroom practices, and students' attitudes toward science. We recommend that other countries' data set can be analyzed to reveal differences between schools with regard to the same factors used in this study for all subject areas. Other international studies such as PISA should be taken into account and similar studies should be carried out based on PISA data set for its science, mathematics, and reading subject matters. Similar study should be also conducted based on PISA 2006 in which science was the main focus to confirm this study's results.

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