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ANALYSIS OF PISA-2015 PERFORMANCE OF TURKISH STUDENTS BY MULTILEVEL STRUCTURAL EQUATION MODELING

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Abstract

The Programme For International Student Assesment (PISA) is an international survey funded by the Organization of Economic Cooperation and Development (OECD). PISA survey is conducted every three years since 2000, to measure and evaluate the educational quality of students aged between 15 and 16. PISA survey is aimed to evaluate students' achievements through the concept of description that they have learned in Science, Mathematics and Reading Skills. In PISA 2015 survey, Science literacy performance of the students were examined. Multilevel Structural Equation Modeling is a multilevel statistical analysis technique used in the analysis of models with complex data structure. Nowadays, , data obtained from many projects such as PISA, TIMSS, and PIRLS, have a complex and hierarchical structure. The MSEM analysis is needed for hierarchical data. The aim of this study is to analyze the created model for PISA 2015 Science Literacy Performance of the Turkish students by using MSEM analysis comparing with the Singaporean students which are the first rank amongst participating countries' students. Turkish and Singapore students were analyzed by using Mplus package program. It has been observed that the model established for both countries is in good fit.

Keywords: Multilevel structural equation modeling, Science literacy, Mplus, PISA 2015

TÜRK ÖĞRENCİLERİN PISA-2015 PERFORMANSININ ÇOK SEVİYELİ YAPISAL EŞİTLİK MODELLEMESİ İLE ANALİZİ

Özet

Uluslararası Öğrenci Değerlendirme Programı (PISA), Ekonomik İşbirliği ve Kalkınma Örgütü (OECD) tarafından finanse edilen uluslararası bir araştırmadır. PISA araştırması, 2000 yılından beri her üç yılda bir 15-16 yaş arası öğrencilerin eğitim kalitesini değerlendirmek ve ölçmek amacıyla gerçekleştirilmektedir. PISA araştırması, öğrencilerin Fen Bilimleri, Matematik ve Okuma Becerilerinde öğrendikleri tanım kavramını kullanarak başarılarını değerlendirmeyi amaçlamaktadır. PISA 2015 araştırmasında, öğrencilerin Fen Bilimleri okuryazarlığı incelenmiştir. Çok seviyeli yapısal eşitlik modellemesi (MSEM), karmaşık veri yapısına sahip modellerin analizinde kullanılan çok seviyeli bir istatistiksel analizdir. Günümüzde, PISA, TIMSS ve PIRLS gibi birçok projeden elde edilen veriler karmaşık ve hiyerarşik bir yapıdadır. MSEM nalizi hiyerarşik veriler için gereklidir. Bu çalışmanın amacı, Türk öğrencilerin 2015 PISA araştırması Fen Bilimleri okuryazarlığı için MSEM analizi kullanılarak oluşturulan modeli analiz etmek ve katılımcı ülkelerin öğrencileri arasında birinci sırada yer alan Singapurlu öğrenciler ile karşılaştırmaktır. Türk ve Singapurlu öğrenciler, MPlus paket programı kullanılarak analiz edilmiştir. Her iki ülke için oluşturulan modellerin iyi uyum gösterdiği gözlenmiştir.

Anahtar Kelimeler: Çok Seviyeli Yapısal Eşitlik Modellemesi, Fen Okuryazarlığı, MPlus, PISA 2015

Cite

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1. Introduction

In the developing and changing world order, the notion of education is known as one of the most important factors affecting lifestyle. The economic, socio-cultural, contemporary and scientific levels of societies are seen as a reflection of the educational process. The quality of education is evaluated within the scope of various projects at the international level. Turkey has participated in the various international projects which evaluate training performance of the countries such as The Trends in International Mathematics and Science Study (TIMSS), The Progress in International Reading Literacy Study (PIRLS), The Programme for International Student Assesment (PISA).

The Programme For Internatıonal Student Assesment (PISA) is an international survey conducted to measure and evaluate the educational quality of students [1]. PISA survey has been conducted every three years since the year 2000. PISA survey has been funded by the Organization of Economic Cooperation and Development (OECD). The main purpose of the PISA survey is to evaluate students' achievements through the concept of description that they have learned in Science, Mathematics and Reading Skills [2]. PISA survey is applied to the students aged between 15 and 16 years.

2. Multilevel Structural Equation Modeling

Structural equation modeling (SEM) is a widely used modeling tool in many areas such as behavioral, commercial and social sciences [3]. SEM is a multivariate statistical analysis which investigates the relationship between multiple results in complex systems with causality [4]. SEM is a modeling method used to test hypotheses based on cause-effect [5].

MSEM is a multilevel statistical analysis technique used in the analysis of models with complex data structure such as social sciences, psychology research and intercultural research [6-10]. Today, data obtained from many projects such as PISA, TIMSS, and PIRLS, have a complex and hierarchical structure. When the data are hierarchical, structural equation modeling analysis is inadequate and multi-level structural equation modeling (MSEM) analysis is needed.

Some of the literatures of MSEM on education studies is given in Table 1.

Table 1. Some of the literatures of MSEM on education studies

Author	Year	Data	Participants	Method
Goldstein et al.[11]	2007	The Programme for International Student Assesment (PISA)	326 schools 8.299 individual	Markov Chain Monte Carlo Method in MSEM
Can et al.[12]	2011	Test of Nonverbal Intelligent (TONI-3)	39 schools 381 students	MSEM
Davidov et al. [7]	2012	European Social Survey (ESS)	25 countries 43.779 individual	MSEM
Atar[13]	2014	Trends in International Mathematics and Science Study (TIMMS)	239 schools 6.928 individual	MSEM

In MSEM, both the between and within-group variance-covariance matrix are evaluated simultaneously. MSEM is a two-level analysis method including within-group and between-group levels [14]. The between group level (i.e. level 2) contains clusters such as countries, schools, faculties, regions, classes, etc. The within group level (i.e. level 1) contains individuals belonging to clusters such as students, teachers, workers, etc.

MSEM decomposes a structural model into within-group and between-group as follows:

Within group: $\eta_{Wgi} = B_W \eta_{Wig} + \zeta_{Wig}$

Between groups: $\eta_{Bg} = \alpha_g + B_B \eta_{Bg} + \zeta_{Bg}$

Where,

g : groups,

i : individuals

B : structural regression coefficients,

α_g : residual terms vector,

ζ : the vector consists of (random) cut points,

η : latent variable [15-17].

Path diagram of the multi-level structural equation model is illustrated in Figure 1 [12, 18].

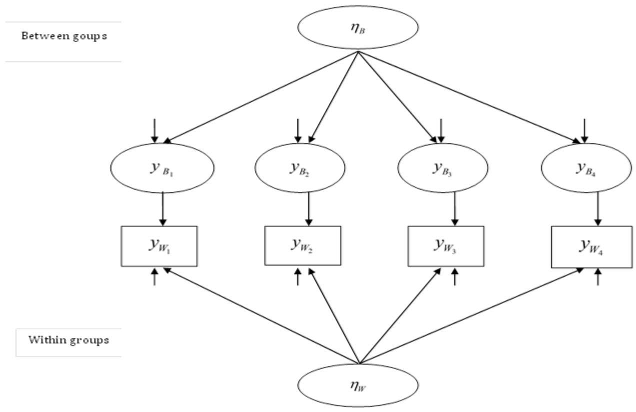

Figure 1. Path diagram of the multi-level structural equation model

It should be determined whether the model created in MSEM is a good fit or acceptable fit. Commonly used goodness of fit indices in the MSEM are Comparative Fit Index (CFI), Tucker Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA) and Standardized Root Mean Residual (SRMR). These indices are shown in Table 2 [19-26].

Table 2. Goodness of fit indices used in MSEM

Goodness of fit index	Good fit / Acceptable fit
CFI	≥0.97 good fit / ≥0.95 acceptable fit.
TLI	≥0.95 good fit / 0.94-0.90 acceptable fit.
RMSEA	≤0.05 good fit / 0.06-0.08 acceptable fit
SRMR	≤0.05 good fit / 0.06-0.08 acceptable fit.

3. Application

In order to examine the PISA 2015 data with the multi-level structural equation modeling (MSEM), at first socio demographic results were obtained by IBM SPSS Statistic 21.0 version. Then, MPlus Program Version 5.1 (32-bit) was used for multi-level structural equation modeling analysis.

It is possible to analyze over-developed, multilevel, latent class and complex models through the Mplus software [20, 27].

In PISA 2015 survey for Turkey, 187 schools (between groups) and 5895 students (within-group) were chosen by stratified random sampling method. For the MSEM analysis, dependent and independent variables are given as follows:

Dependent variable:

Y: Science achievement score (SAS)

Independent variables (Within-group):

Selected from the student questionnaire as follows:

X1: Gender
X2: Family support
X3: Science working hours
X4: Activity in science class
X5: Teacher's comment in science class
X6: Teacher support in science class
X7: Science self-concept
X8: Interest in science
X9: Science activities
X10: Program type

Independent variables (Between-groups):

Selected from the school questionnaire as follows:

X11: Settlement
X12: Number of smart boards
X13: Science equipment
X14: Laboratory
X15: Laboratory material
X16: School type
X17: Teaching hours

Class variable;

Clus: Number of schools.

4. Results

In the PISA 2015 survey, Science literacy performance of the students were examined. In this study, at first, descriptive statistics of the variables in the model were evaluated. Then, model fitting of the created model was evaluated.

Descriptive statistics for Turkey are shown in Table 3.

Constructed model of the MSEM for Turkey is given as:

$$Y_{ij} = \gamma_{00} + \gamma_{10}X1 + \gamma_{20}X2 + \gamma_{30}X3 + \gamma_{40}X4 + \gamma_{50}X5 + \gamma_{60}X6 + \gamma_{70}X7 + \gamma_{80}X8 + \gamma_{90}X9 + \gamma_{100}X10 + \gamma_{01}X11 + \gamma_{02}X12 + \gamma_{03}X13 + \gamma_{04}X14 + \gamma_{05}X15 + \gamma_{06}X16 + \gamma_{07}X17 + \tau_{0j} + e_{ij} \quad (1)$$

The path diagram of the MSEM for Turkey is shown in Figure 2.

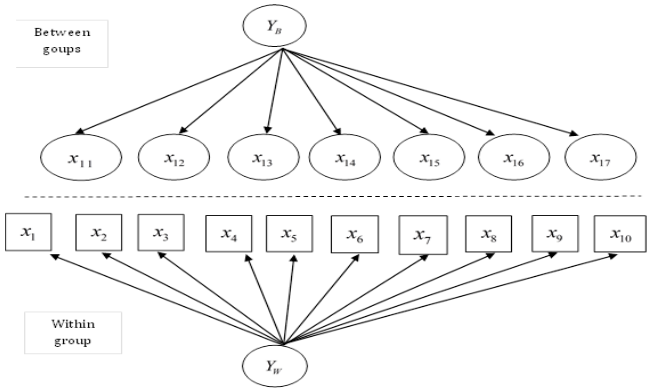

Figure 2. The path diagram of the MSEM for Turkey

Mplus multilevel structural equation modeling results for Turkey is given in Table 4.

When the within-group results of the Mplus program for Turkey are examined, the science achievement score (Y) of the students do not vary according to the following variables;

-teacher's comment in science class (X5 = 0.235 > p = 0.05)

-program type (X10 = 0.750> p = 0.05)

Variables affecting the science achievement score (Y) are as follows:

-gender (X1=0.002< p=0.05),

-family support (X2=0.000 < p=0.05),

-science working hours (X3=0.000 < p=0.05),

-activities in science class (X4=0.000 < p=0.05),

-teacher support in science course (X6=0.000 < p=0.05),

-science self-concept (X7=0.000 < p=0.05),

-interest in science (X8=0.000 < p=0.05)

-science activities (X9=0.000 < p=0.05).

When the between-group results of the Mplus program for Turkey are examined, the science achievement score (Y) varies according to the following variables

-settlement (X11=0.048 < p=0.05,

-number of smart boards (X12=0.000 < p=0.05)

-science equipment variables (X13=0.043 < p=0.05).

Other variables obtained from the school questionnare do not affect the science achievement score (Y);

-laboratory (X14 = 0.784 > p = 0.05).

-laboratory material (X15 = 0.140 > p = 0.05).

-type of school (X16 = 0.229 > p = 0.05).

-teaching hours (X17 = 0.528 > p = 0.05).

Goodness of fit indices of the created model for Turkey are obtained as;

-CFI= 1.000 (> 0.97 good fit)

-TLI = 1.000 (> 0.95 good fit)

-RMSEA = 0.000 (< 0.05 good fit)

-SRMR = 0.000 (< 0.05 good fit)

According to these results, it is determined that the created model for Turkey is a multi-level structural equation model with good fit [28].

In PISA 2015, the mean score in science for OECD countries is 493 points. Singapore with a mean score of 556 points, outperforms all other participating countries in science.

In a similar manner, MSEM analysis are conducted on Singaporean students. Created model expressed by ''Y_{ij}'' for Singapore is;

$$Y_{ij} = \gamma_{00} + \gamma_{10}X1 + \gamma_{20}X2 + \gamma_{30}X3 + \gamma_{40}X4 + \gamma_{50}X5 + \gamma_{60}X6 + \gamma_{70}X7 + \gamma_{80}X8 + \gamma_{90}X9 + \gamma_{100}X10 + \gamma_{01}X11 + \gamma_{02}X12 + \gamma_{03}X13 + \gamma_{04}X14 + \gamma_{05}X15 + \tau_{0j} + e_{ij} \quad (2)$$

Descriptive statistics for Singapore are shown in Table 5.

The path diagram of the MSEM for Singapore is illustrated in Figure 3.

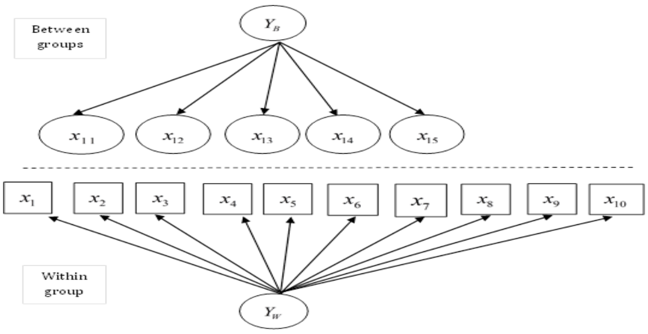

Figure 3. The path diagram of the MSEM for Singapore

Mplus multilevel structural equation modeling results for Singapore is given in Table 6.

The science achievement score (Y) of the Singaporean students do not vary according to the following variables;

-family support (X2 = 0.359 > p = 0.05)

-teacher support in science class (X6 = 0.645> p = 0.05)

Variables affecting the science achievement score (Y) are as follows:

-gender (X1=0.006<p=0.05),

-study hours in science (X3=0.047<p=0.05),

-activities in science class (X4=0.000<p=0.05),

-teacher's comment in science class (X5=0.010<p=0.05),

-science self-concept (X7=0.000 < p=0.05),

-interest in science (X8=0.000 < p=0.05),

-science activities (X9=0.000 < p=0.05)

-program type (X10=0.000 < p=0.05).

When the between-group results of the Mplus program for Singapore are examined, the science achievement score (Y) varies according to the following variables

- number of smart boards (X11 = 0.001< p = 0.05).
- school type (X14 = 0.000 < p = 0.05).
- teaching hours (X15 = 0.000 < p = 0.05).

Other variables obtained from the school questionnare do not affect the science achievement score (Y);

- science equipment (X12=0.890 > p=0.05).
- laboratory (X13=0.083 > p=0.05).

Goodness of fit indices of the created model for Singapore are obtained as;

-CFI= 1.000 (> 0.97 good fit)

-TLI = 1.000 (> 0.95 good fit)

-RMSEA = 0.000 (< 0.05 good fit)

-SRMR = 0.000 (< 0.05 good fit)

According to these results, it is determined that the model created for Singapore is a multi-level structural equation model with good fit [28].

Table 3. Descriptive statistics for Turkey

Variables	Frequency	Percentage (%)	Mean	Standard Deviation	Min. Value	Max. Value
Gender (X1)	**5895**				**1**	**2**
Female (1)	2938	49.8				
Male (2)	2957	50.2				
Family support (X2)	**5895**		12.86	2.87	1	16
Study hours in science (X3)	**5895**		5.34	4.37	0	30
Activity in science class (X4)	**5895**		10.59	3.12	1	16
Teacher's comment in science class (X5)	**5895**		9.90	2.85	2	16
Teacher support in science class (X6)	**5895**		7.38	2.28	1	12
Science self-concept(X7)	**5895**		13.32	4.17	1	20
Interest in science (X8)	**5895**		12.78	4.31	1	25
Science activities (X9)	**5895**		26.36	7.07	1	36
Program type (X10)	**5895**				1	3
Basic education (1)	121	2.1				
General secondary education (2)	3241	55.0				
Vocational and Technical sec. edu. (3)	2533	43.0				
Settlement (X11)	**5895**		3.96	1.01	1	5
A village, a village or a rural area (1)	72	1.2				
Small town (2)	372	6.3				
One town (3)	1776	30.1				
One city (4)	1286	21.8				
Great city (5)	2385	40.5				
Number of smart boards (X12)	**5895**		21	16	0	60
Science equipment (X13)	**5895**				1	2
Yes (1)	1618	27.4				
No (2)	4277	72.6				
Laboratory (X14)	**5895**				1	2
Yes (1)	1769	30.0				
No (2)	4126	70.0				
Laboratory material (X15)	**5895**				1	2
Yes (1)	1716	29.1				
No (2)	4179	70.9				
School type (X16)	**5895**				1	2
Public school (1)	5653	95.9				
Private school (2)	242	4.1				
ing hours(X17)	**5895**		7.13	5.97	1	53
Clus (Class)	**187**					
Science achievement score (SAS)	**5895**		**422.45**	**77.13**	**197.7**	**707.9**

Table 4. Mplus multilevel structural equation modeling results for Turkey

Variables	Estimation	Standard error	Estimation/ Standard error	p value
Independent variable				
Science achievement score (Y)	421.869	31.674	13.319	0.000*
Within-group variables				
Gender (X1)	0.054	0.017	3.144	0.002*
Family support (X2)	0.049	0.013	3.729	0.000*
Study hours in science (X3)	-0.076	0.014	-5.635	0.000*
Activity in science class (X4)	0.114	0.013	8.425	0.000*
Teacher's comment in science class (X5)	0.016	0.014	1.187	0.235
Teacher support in science class (X6)	0.077	0.014	5.563	0.000*
Science self-concept (X7)	0.116	0.014	8.341	0.000*
Interest in science (X8)	0.051	0.014	3.656	0.000*
Science activities (X9)	0.091	0.014	6.499	0.000*
Program type (X10)	-0.017	0.054	-0.319	0.750
Between-groups variables				
Settlement (X11)	0.150	0.076	1.966	0.048*
Number of smart boards (X12)	0.282	0.062	4.563	0.000*

Science equipment (X13)	-0.229	0.123	-1.856	0.043*
Laboratory (X14)	0.033	0.121	0.274	0.784
Laboratory material (X15)	-0.147	0.100	-1.476	0.140
School type (X16)	0.073	0.060	1.204	0.229
Teacher working time (X17)	-0.030	0.047	-0.632	0.528

*p value <0.05

Table 5. Descriptive statistics for Singapore

Variables	Frequency	Percentage (%)	Mean	Standard Deviation	Min. Value	Max. Value
Gender (X1)	**6115**				**1**	**2**
Female (1)	2973	48.6				
Male (2)	3142	51.4				
Family support (X2)	**6115**		**13.03**	**2.43**	**2**	**16**
Science working hours (X3)	**6115**		**6.15**	**4.88**	**0**	**30**
Activity in science class (X4)	**6115**		**11.64**	**3.25**	**3**	**16**
Teacher's comment in science class (X5)	**6115**		**11.59**	**3.59**	**3**	**16**
Teacher support in science class (X6)	**6115**		**8.61**	**2.75**	**2**	**12**
Science self-concept (X7)	**6115**		**15.01**	**3.42**	**2**	**20**
Interest in science (X8)	**6115**		**14.35**	**3.71**	**2**	**25**
Science activities (X9)	**6115**		**29.7**	**5.6**	**3**	**36**
Program type (X10)	**6115**				**1**	**3**
Basic education (1)	113	1.8				
General secondary education (2)	5993	98.0				
Vocational and Technical sec. edu. (3)	9	0.2				
Number of smart boards (X11)	**6115**		**5**	**9**	**0**	**85**
Science equipment (X12)	**6115**				**1**	**2**
Yes (1)	5844	95.6				
No (2)	271	4.4				
Laboratory (X13)	**6115**				**1**	**2**
Yes (1)	5372	87.8				
No (2)	743	12.2				
School type (X14)	**6115**				**1**	**2**
Public School (1)	5717	93.5				
Private School (2)	398	6.5				
Teacher working time (X15)	**6115**		**18.5**	**9.6**	**4**	**89**
Clus (Class)	**177**					
Science achievement score (Y)	**6115**		**546.39**	**104.5**	**228**	**888**

Table 6. Mplus multilevel structural equation modeling results for Singapore

Variables	Estimation	Standard error	Estimation/ Standard error	p value
Independent variable				
Science achievement score (Y)	456.474	26.629	17.142	0.000*
Within-group variables				

Gender (X1)	0.008	0.013	0.603	0.006*
Family support (X2)	0.013	0.014	0.917	0.359
Science working hours (X3)	0.019	0.013	1.415	0.047*
Activity in science class (X4)	-0.109	0.015	-7.381	0.000*
Teacher's comment in science class (X5)	-0.049	0.019	-2.559	0.010*
Teacher support in science class (X6)	-0.009	0.019	-0.461	0.645
Science self-concept (X7)	0.271	0.014	19.076	0.000*
Interest in science (X8)	0.096	0.016	6.171	0.000*
Science activities (X9)	0.101	0.016	6.378	0.000*
Program type (X10)	0.131	0.013	9.910	0.000*
Between-groups variables				
Number of smart boards (X11)	-0.202	0.058	-3.465	0.001*
Science equipment (X12)	0.009	0.068	0.138	0.890
Laboratory (X13)	-0.115	0.067	-1.731	0.083
School type (X14)	0.210	0.053	3.981	0.000*
Teaching hours(X15)	0.600	0.054	11.183	0.000*

5. Conclusion

It is known that the education is one of the most important factors affecting the lifestyle in the developing and changing world order. Nowadays, it is known that multilevel structural equation modeling analysis has been widely used in international researches such as PISA, TIMSS and PIRLS. The Mplus program has effectively used for the analysis of the hierarchical data in multilevel structural equation modeling.

When PISA 2015 science literacy results for Turkish students are evaluated, it could be said that the success in the science test of the Turkish students is affected by 8 variables taken from the student questionnaire and is affected by 3 variables from the school questionnaire.

- According to the student questionnaire; Gender, family support, activity in science class, teacher support in the science class, science self-concept, interest in science, and science activities increase the science achievement score of Turkish students. However, the increase in science working hours negatively affects the science achievement score.
- According to the school questionnaire; Science achievement score of Turkish students is increased according to the settlement and number of smart boards. However, decrease in the science equipment in the schools causes science achievement scores to decrease.

When PISA 2015 science literacy results for Singaporean students are evaluated, it could be said that the success in the science test of the Singaporean students is affected by 8 variables taken from the student questionnaire and is affected by 3 variables from the school questionnaire.

- According to the student questionnaire; Gender, science working hours, science self-concept, interest in science, science activities and program type increase the science achievement score of Singaporean students. However, the increase in activity in science class and teacher's comment in science class negatively affects the science achievement score.
- According to the school questionnaire; Science achievement score of Singaporean students has increased with school type and teaching hours. However, decrease in the number of smart boards in schools causes science achievement scores to decrease.

According to the report on PISA 2015 results [2], Singaporean students surpassed all other participating countries/economies in science with mean score 556. Turkish students with mean score 425 ranked as 52 among the 72 participating countries. In Turkey, the course density was observed to be high. Therefore, students' interest in science has decreased. However, the lower course density has increased the science achievement score in Singapore.

In addition, students with higher study hours (6.15±4.88) in Singapore are more successful than

Turkish students with the same study hours (5.34±4.37). It was observed that working hours of Turkish teachers (7.13±5.97) had no effect on science achievement score of Turkish students, but the working hours of Singaporean teachers (18.5±9.6) affected the science achievement score of Singaporean students positively. Although the impact of family support to students is high in Turkey, science achievement scores of Turkish students are lower than the Singaporean students.

As a result, difference between the Turkish students and Singaporean students is obvious in terms of science achievement score. For this reason, it can be suggested that the Turkish education system should be revised by examining the Singapore education system in detailed.

6. Acknowledgment

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