Hindawi Publishing Corporation
Education Research International
Volume 2014, Article ID 490371, 8 pages
http://dx.doi.org/10.1155/2014/490371

Research Article

A Structural Equation Modeling on Factors of How Experienced Teachers Affect the Students' Science and Mathematics Achievements

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Received 24 January 2014; Revised 27 May 2014; Accepted 2 June 2014; Published 24 June 2014

Academic Editor: Yi-Shun Wang

The main purpose of this study was to propose a model for how elementary school students' science and mathematics achievements in their schools and in Level Determination Exam (SBS) depend on the number of teachers and expert teachers in their schools. The sample of the study was 5672 elementary students for the purpose of the study, the number of teachers and expert teachers who worked in sample schools has been defined as independent variables, and students' science and mathematics achievements in their schools and in SBS exam have been defined as dependent variables. The data obtained from school administrations were analyzed using structural equation modeling to analyze relations among students' science and mathematics grades in their schools and science and mathematics achievements in SBS exam and the number of teachers and expert teachers in their school. As a result of the analysis, it has been observed that established model has acceptable fit indices and an increasing number of teachers and expert teachers have positive effects on students' science and mathematics achievements.

1. Introduction and Literature Review

The main purpose of education systems is to reveal desired behaviors to students. The most important of these desired behaviors is the academic achievement of the students performed at school. Students' academic success and factors affecting students' science and mathematics achievement parallel to this study have been research subject of many researchers [1–13] as well as many different institutions and have come to the fore in the results of universally made exams such as TIMSS and PISA. The third international mathematics and science study (TIMSS) is the broadest study which is carried out by IAE (International Association for the Evaluation of Educational Achievement) and takes in the students of 38 countries in which Turkey was included in 1999. The main purpose of TIMSS, generalizability of which is admitted to be high in terms of sample which is used also by researchers [4], is to constitute a basis which will provide the countries to see their own programs and teaching methods and present the relation between the programs and methods with students' mathematics and science achievements, in order to develop the teaching and learning of mathematics and science worldwide [14]. According to TIMSS reports, as a result of the exam which is made to 8th grade students who receive education in Turkey, Turkey is ranked at the 33rd place in science and 31st place in mathematics [15, 16]. Similar results are seen in the results of Program for International Student Assessment made by OECD. PISA results indicate that Turkey, among many countries, is ranked at a place that can be regarded as the last place in science and mathematics achievement [11]. Besides institutional studies such as TIMSS and PISA, the factors affecting students' achievement as well as their achievement at school are also analyzed by education researchers. Researches show that there are several different extents of these factors such as intelligence, students' cognitive and learning styles, and environmental factors [17].

One of the most important environmental factors which affect the students' academic achievement's configuration process is the school factor. Properties like school's physical medium, physical resources, teacher/student rate, teacher

sufficiency, number of teachers, age of teachers, teacher experiences, and teachers' level of education (having master's or doctoral degree) stand out as school factor. Wendling and Cohen [18] determined a positive correlation between teachers' average experiences, having master's or doctoral degree variables, and students' achievements in the study they made. Greenwald et al. [19] stated that teachers having more than 5-year experience are more productive; Goldhaber and Brewer [20] with Wayne and Youngs [21] stated that the students of teachers who have done graduate work are more successful than the students of the teachers who have not done graduate work. Hanushek and Rivkin [22] stated that there is low correlation between teachers' experience and education and students' performance. In his study, Hanushek [23] stated that there is a very low effect of teacher sufficiency as the explanatory factor of student achievement, analysing the reports of National Assessment of Educational Progress (NAEP, 1969–1999), which is made in the USA, and TIMSS, which is made worldwide.

Moreover, they reported that it was determined in 28 out of 46 studies, in which the correlation between the teacher experience and achievement is researched, that there was statistically insignificant correlation and in 18 studies that there was a significant correlation (16 positive, 2 negative). Üzkurt and Koçakoğlu [12] examined the effects of students' achievements in school on SBS and determined that there is a significant correlation between students' mathematics and science achievements in school and SBS.

And in this study the effects of the mentioned variables, age, experience, and education levels of the teachers, on students' mathematics and science achievements in school and SBS exams are examined with SEM (structural equation modeling). When the research studies are examined, it is observed that the study which examines the effects of school inputs, which also constitutes the independent variables of this study, on the student achievements is generally examined with correlation analysis. The indirect and direct relations among variables cannot be distinguished completely in the studies that are made only by relations among correlations as it is going to be stated in the method part. In this regard, the results of this study, which applied SEM, will fill in the gaps in the literature.

2. Methodology

2.1. Population and Sample. The elementary schools in Turkey constitute the population. The sample of the study includes 5672 7th grade (2899) and 8th (2773) grade students from 25 elementary schools of provinces of Adana, Ağrı, Ankara, Çorum, Diyarbakır, İstanbul, İzmir, Kocaeli, Mardin, Mersin, Muğla, Rize, Şanlıurfa, Trabzon, and Van. To promote the generalizability of results from the sample to the population, at least two provinces in each geographical region in Turkey were chosen for study.

2.2. Data Collection Process. The contact has been made with the administrators of the schools included in this study. The number of teachers and expert teachers working at their schools, ages of the teachers, the length of their experience, mathematics and science grades of the 7th and 8th grade students who entered SBS in 2009, and the number of correct answers of the same students in mathematics and science in SBS are asked from the school administrators. Since the data used in the study started to be collected from the beginning of 2009-2010 academic year, only 7th and 8th grade students' previous year's SBS scores and mathematics and science grades are examined. The statistics and frequency rates of the data of teachers taken from the school administrator are shown in Table 1.

Table 1: The number, the length of experience, and the age of teachers.

Teacher numbers		Age of teachers		Teacher experience	
Teachers	958	20–30 years	230	0–5 years	177
Expert teachers	102	30–40 years	439	5–10 years	222
		40–50 years	261	10–15 years	260
		50–60 years	114	15–20 years	225
		Over 60	16	20–25 years	95
				Over 25	81
Total	**1060**		**1060**		**1060**

2.3. Procedure. The most important features of scientific studies include measuring and relating the variables and revealing the causality (if any). However, observable variables such as the students' scores, income, and age can be directly measured, while latent variables such as intelligence and achievement cannot be directly measured. In such cases, it is important to establish regression equalities that show how endogenous structures (predicted-endogenous) are linked with exogenous structures (predictive-exogenous) [24] and to benefit from a multivariate statistical analysis approach which has a wide usage area in combining measurement principles like the structural equation model (SEM) [25].

SEM is a new and very strong analysis technique which consists of combination of multivariate statistical techniques and which is used commonly by the scientists who are engaged in social sciences, like economists, education, and marketing researchers. SEM is an effective model testing and improving method that enables theoretical models to be tested as a whole and that can explain the cause and effect relationship of the variables in mixed hypotheses which are related to the models based on statistical dependence. It is based on the testing of a model of the relations among the variables that stands in researcher's mind before the research is made, via data acquired from the research [25].

Being a prolongation of general regression analysis, which makes more than one regression analysis at a time, SEM can be used in testing traditional models. But, differently, it is a useful method also in the situations, where more complicated relations (confirmatory factor analysis, time series, etc.) emerge [26]. The working areas are theoretic structures that are represented by latent variables. Basically, it is the combination of factor analysis and regression analysis. It scrutinizes the suitability of the estimated covariance matrix,

which is composed, according to the theoretical structure, of the covariance matrix of observed data [27]. SEM, while resembling the regression analysis mostly, is a very powerful statistical technique that models interactions, can cope with nonlinear situations, lets correlation among independent variables, includes measurement errors to the model, regards measurement errors which have correlation among themselves, and exposes and tests the relations among multiple independent and dependent latent variables, each of which is measured with more than one observed variable. While the other multivariate statistical methods have exploratory and descriptive features, SEM presents a confirmatory structure. And this reveals the superior sides of SEM in hypothesis test. Moreover, while the other kinds of multivariate statistics cannot determine and correct measurement errors, SEM includes almost all the measurement parameters and comes to the conclusion according to this [28].

Because of the reasons explained above, and since the methods used in explaining students' achievements are generally limited to correlation, regression, and factor analysis, it is thought that working with SEM, which is an analysis method that can measure the stated variables more comprehensively, significantly, and reliably, will contribute to the literature.

2.4. The Model Construction. In the study, age and experience of teachers in schools are thought of besides the number of teachers and expert teachers as teacher related variables, the effect of which on student's achievements is thought to be examined. Although at first it was thought that, besides the teacher numbers, age and experience of the teachers should also take part in the model, it is decided to use only teachers and expert teachers numbers as independent variables because of the reasons listed below.

(i) The obligation of having at least 7 years of experience to be expert teacher and 6 years of experience as an expert teacher to be head teacher is imposed during which Turkish Ministry of Education switched to the application (implementation, practice) of expert and head teachership.

(ii) Although the passing to expert teachership is made, the required duration is not being completed during data collection in order to be head teacher.

(iii) After 4-5 years since that time, teachers, who gained the right to be expert teachers, have gained this right until the time data has been collected, despite the expert teachers' having at least 11-12 years of experience now.

(iv) The reality is that, depending on the experience, the age of expert teachers is also increasing.

Since it is decided that the number of expert teachers also reflects the work experience of the teachers in school because of the reasons mentioned above, teachers' ages and work experience that are thought to be effective for students' achievements are removed from the model. Finally, by setting the model given in Figure 1, whether the model fits the collected data was tested and the effects of teachers and expert teachers on students' mathematics and science achievements were examined in the model. The model is mainly based on the hypotheses that the teacher factor is effective for students' mathematics and science achievements in school, and later on both teacher factor and students' mathematics and science achievements are effective for students' mathematics and science achievements in SBS.

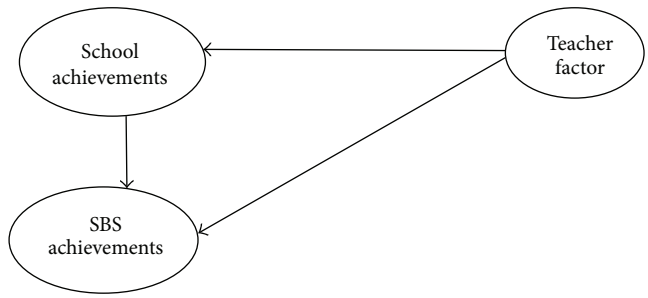

Figure 1: The model showing the effects of teacher factor on students' mathematics and science achievements in school and SBS.

2.5. Findings. Descriptive statistics of (median, standard deviation, standard error of the mean, range, and correlations between variables) the variables used in the study are given in Tables 2 and 3.

When correlations in Table 3 are analyzed, it is seen that the relation between the number of teachers and students' mathematics and science achievements in the schools is not statistically significant but there is a positive relation between this variable and students' mathematics and science achievements in SBS ($P < .01$). Moreover, it is seen that there is a positively significant relation between the number of expert teachers in the schools and students' mathematics and science achievements in their school and SBS ($P < .01$).

In the study, firstly setting a suitable model for the effects of teacher factor on student achievements and secondly the effects of the variables taking part in this model on success are examined. For model testing, the common 9 fit indices used in testing the suitability of the models are used and rates found with their acceptable ranges are given in Table 4.

When Table 4 is analyzed, the 8 out of 9 fit indices rates are seen to be in acceptable ranges. Only χ^2/df rate is seen not to be in an acceptable range. Since the sample used in the study is 5672 and χ^2/df index's being affected by the extent of the sample can cause this rate not to be in acceptable ranges, this index is not considered alone. Thus, it is decided that the model is a suitable model with regard to other 8 indices.

2.6. Structural Equation Model. Established structural equation model gives results compatible with hypothesis of the study. Depending on the hypothesis, teacher factor has a positive contribution on students' achievements in school ($\beta = .16$, $P < .001$). Moreover, both teacher factor and school achievement have a positive contribution on students' SBS achievements (resp., $\beta = .13$, $P < .001$ and $\beta = .90$, $P < .001$). Also, students' achievements in school and teacher

Table 2: Descriptive statistics of the variables used in the model.

Variable	Mean	Standard deviation	Standard error of the mean	Range
Teachers number	44.66	13.917	.185	15–68
Expert teachers number	4.96	4.032	.054	0–15
Science achievements in school	63.706	16.939	.224916	17.51–100
Mathematics achievements in school	59.421	18.372	.243946	12.82–100
Science achievements in SBS	8.32	3.3	.044	0–18
Mathematics achievements in SBS	5.33	2.737	.036	0–18

Table 3: Correlations belonging to variables used in the model.

Variables	1	2	3	4	5	6
Teachers number	1	.282**	−.014	.018	.073**	.071**
Expert teachers number		1	.148**	.096**	.144**	.179**
Science achievements in school			1	.820**	.702**	.452**
Mathematics achievements in school				1	.658**	.505**
Science achievements in SBS					1	.473**
Mathematics achievements in SBS						1

** $P < .01$

Table 4: Fit indices concerning the established model.

Fit indices		Calculated rate	Acceptable range
χ^2/df	(χ^2 = 325,397, df = 6, P = .001)	54,233	Between 2 and 5
GFI		.982	>.90
AGFI		.938	>.90
CFI		.976	>.90
NFI		.975	>.90
RFI		.938	>.90
IFI		.976	>.90
TLI		.939	>.90
RMSEA		.097	<.100

To see the related literatures for fit indices, please look at the below.
[for χ^2/df, see Marsh and Hocevar [29]; for RMSEA, see Browne et al. [30]; for NFI, GFI, AGFI, and CFI, see Byrne [31] and Jöreskog and Sörbom [32]; for TLI, see Bentler and Bonett [33]; for IFI, see Bollen [34]; for RFI, see Bollen [35]].

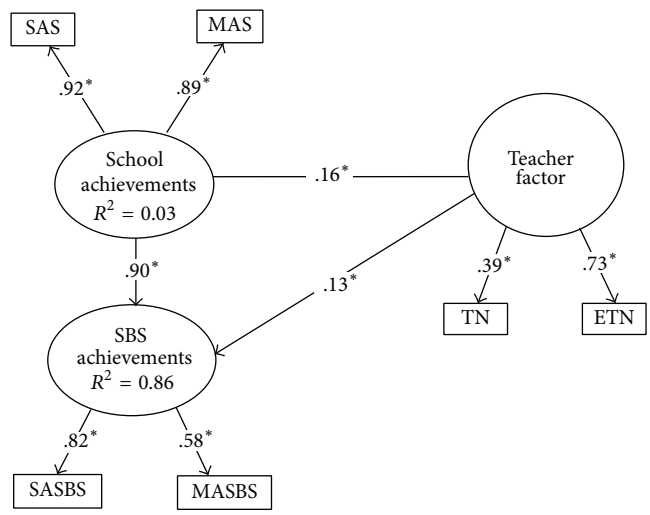

Figure 2: The effects of teacher factor on students' achievements in school and SBS. SAS: science achievements in school. MAS: mathematics achievements in school. SASBS: science achievements in SBS. MASBS: mathematics achievements in SBS. TN: number of teachers. ETN: number of expert teachers. * $P < .001$.

factor in the model explain %86 of the increase in students' SBS achievements. The results about the model are given in Figure 2.

In Figure 2, the direct effects between the variables in the model are given but the biggest superiority of SEM to regression and correlation analysis is that we can also see indirect latent effects. The direct, indirect, and total effects between the variables in the model are given in Table 5.

When Table 5 is analyzed, it is seen that while all of the effect rates of teacher factor on school achievements, ETN, and TN consist of direct effects and all of the effect rates of teacher factor on MASBS, MAS, SASBS, and SAS consist of only indirect effects, the total effects of teacher factor on SBS consist of the sum of direct and indirect effects. Similarly, all of the total effect rates of school achievements on SBS, SAS, and MAS consist of direct effects and all of the total effect rates of school achievement on MASBS and SASBS consist of indirect effects. Besides, direct effects constitute all of the total effects of students' SBS achievements, which is the last factor, on SASBS and MASBS.

3. Discussion and Conclusion

In this study, the effects of the teacher factor on students' mathematics and science achievements in school and SBS are examined. Teacher factor, teacher and expert teacher numbers in schools, is taken as subdimension of independent variable, as students' mathematics and science achievements

Table 5: Direct, indirect, and total effects between the variables in the model.

Explanatory factor	Dependent variable	Total effects	Direct effects	Indirect effects
Teacher factor	School achievement	.164	.164	.000
	SBS achievement	.273	.126	.147
	ETN	.731	.731	.000
	TN	.385	.385	.000
	MASBS	.158	.000	.158
	SASBS	.223	.000	.223
	MAS	.147	.000	.147
	SAS	.151	.000	.151
School achievements	School achievement	.000	.000	.000
	SBS achievement	.897	.897	.000
	ETN	.000	.000	.000
	TN	.000	.000	.000
	MASBS	.519	.000	.519
	SASBS	.733	.000	.733
	MAS	.892	.892	.000
	SAS	.919	.919	.000
SBS achievements	School achievement	.000	.000	.000
	SBS achievement	.000	.000	.000
	ETN	.000	.000	.000
	TN	.000	.000	.000
	MASBS	.578	.578	.000
	SASBS	.818	.818	.000
	MAS	.000	.000	.000
	SAS	.000	.000	.000

SAS: science achievements in school. MAS: mathematics achievements in school. SASBS: science achievements in SBS. MASBS: mathematics achievements in SBS. TN: number of teachers. ETN: number of expert teachers.

in school and SBS are taken as subdimension of the other two dependent variables. Essentially, this study is set on the hypotheses that teacher and expert teacher numbers in schools affect students' mathematics and science achievements in school and that afterwards teacher and expert teacher numbers with students' mathematics and science achievements in school affect their mathematics and science achievements in SBS. For this purpose, at first, the model is analyzed whether it is suitable to measure the cause and effect relationship between the tested variables. According to fit indices, except for χ^2/df, the model moderately fits the data. When Table 4 is examined, χ^2/df index rate which is so much above acceptability range is found. This index is a method used in model fit and to find the proportion of chi-square rate to degree of freedom. This index rate, as can be understood from degree of freedom, is dependent on the number of samples. Normally, the rate found in chi-square analysis is supposed to be greater, in other words significant, than critical chi-square rate; the rate in the models of SEM is rather preferred to be as low as possible for the approval of hypothesis tested. And sample number's being so big, 5672, has caused chi-square rate, which is going to be found, to be greater accordingly. The proportion of this rate to the degree of freedom has been greatly in parallel with this. Many researchers test model fit, considering other indices that are not affected by sample size too rather than χ^2/df index since χ^2/df gives great rates affected by sample size. So, in this study, 8 more different fit indices that are not dependent on sample size are examined and since all of these 8 indices have acceptable fit rates, it is concluded that established model is suitable to measure the variables in the study.

According to the fitted model, teacher factor is observed to contribute positively to students' mathematics and science achievements in school ($\beta = .16$, $P < .001$). Moreover, both teacher factor and school achievements are seen to affect students' mathematics and science achievements in SBS positively (resp., $\beta = .13$, $P < .001$ and $\beta = .90$, $P < .001$). Besides, the teacher factor in model and students' achievements in school explain 86% of the increase (variance) of students' achievements in SBS ($R^2 = .86$). $R^2 = .86$ rate shows that variables in this model explain the students' SBS achievements with very high rates. Contrary to this, it is seen that teacher factor, although it has a significant effect, explains a very low amount of the variance in students' mathematics and science achievements in school alone ($R^2 = .03$). Handling only teacher factor in explaining student achievement is seen as the biggest deficiency of this study.

Unlike other research studies discussing only linear relationships, in this study, the cause and effect relationships among the variables were analyzed using SEM which is more comprehensive, enables analyzing latent and observed variables together, and is a kind of analysis that presents factor

loads among observed variables that belong to latent variables itself together. It is immediately noticed when Tables 3 and 5 are examined that this approach is able to show some relations that cannot be noticed in correlation analysis. When looking at the correlation rates in Table 3, the relation between teacher numbers and students' mathematics and science achievements in school is seen statistically insignificant. If the study results are interpreted by only considering correlation rates that are found, it can be concluded that there is no relation between teacher numbers and achievement; SEM shows us that the rates found in correlation analysis actually show the direct effect between cause and effect variables and that the indirect effects which we cannot notice can have an additive or reducing contribution to the observed direct effect (Table 5). Table 5 shows that teacher factor has a considerable number of indirect effects on students' mathematics and science achievements in school ($\beta = .151$ and $\beta = .147$, resp.). If we look at the situation only correlational, we would have measured the direct effects between variables and ignored the indirect effects. And, just at this point, the superiority of SEM on correlation analysis shows itself.

The comparison of the findings of this study with the other studies, in which the effects of the same variables on students' achievements are examined, is given below.

Many researchers have studied teacher-based features similar to those considered in the present study. While for some researchers there is a positive or negative correlation between the depicted factors (teacher experiences) and students' achievements, for some researchers this relation is at an insignificant rate. Wending and Cohen [18] in their study determined a positive relation between teachers' average experience, their master's or doctoral degree variables, and students' achievements. Hanushek and Rivkin [22] found that there is a low correlation between teachers' education and experience variables and student performances. As seen in Table 3, the findings of Wendling and Cohen [18] and Hanushek and Rivkin [22] support the findings of this study. Greenwald et al. [19] reported that teachers with more than 5 years of experience are more productive; Goldhaber and Brewer [20] and Wayne and Youngs [21] informed that the students of teachers who have master's degree are more successful than those of the teachers who do not have master's degree. The studies of Goldhaber and Brewer [20] and Wayne and Youngs [21] support the findings of the study, as well. Harbison and Hanushek [36], having made the most comprehensive study about the effects of school variables on students' achievements, arranged 96 study results (after compiling them) concerning the effective school inputs in developing countries, whether they are statistically significant or not. While the results found in 26 out of 63 studies they made, related to teacher education, are statistically insignificant, the results of the remainder 37 studies report that there is a significant relation (35 positive, 2 negative) between teacher education and students' achievements. Moreover, they reported that in 28 out of 46 studies, in which the correlation between teacher experience and success is examined, a statistically insignificant relation is determined and in 18 studies a significant correlation (16 positive, 2 negative) is determined. Hanushek [23], in his study, examining the reports of National Assessment of Educational Progress (NAEP, 1969–1999) which is made in the USA and of TIMSS which is made worldwide, argues that teacher competence has a very low effect as a factor explaining students' achievements, but it would also be wrong to examine teacher competence alone in a linear way as one of the variables that affect students' achievements which is very complicated.

Üzkurt and Koçakoğlu [12] examined the relation of students' achievements in school to their achievements in SBS in a correlation analysis and determined that there is a significant correlation between students' mathematics and science achievements in school and students' mathematics and science achievements in SBS. Correlation rates in Table 3 show parallelism with the results of the study of Üzkurt and Koçakoğlu.

Making comparison of the findings gained in this study with those gained in similar studies, only correlation analysis results in Table 3 and the findings of the studies analyzing the same issues with correlation analysis could be compared. Although cause and effect relationship between variables used in this study is investigated with structural equation modelling rather than correlation analysis and since no studies were encountered in the literatures that show parallelism with the method of this study, the comparison of the results, found with SEM, with similar studies could not be made.

In conclusion, this study extends the studies employed correlation, regression, and factor analyses which have been commonly used to determine variables related to students' achievement by considering latent variables in addition to observed variables. Thus this study contributed to the literature using SEM with those variables. Sample size of the study was quite large and choosing cities from all regions of Turkey increased generalizability of the results to all over to Turkey. On the other hand, that few variables were included into the model can be considered a limitation of the study.

Based on the findings of this study, the following suggestions can be offered.

(i) In addition to the variables studied in the present study, the model can be extended by adding other related variables such as other school variables, socioeconomic features of students, and financial politics of government on education.

(ii) Since study findings show that teacher competence has a positive effect on students' achievements, opportunities should be provided to the teachers that will contribute to their education and also to their professional life. For doing this, teachers can join in-service training and they can be encouraged to continue graduate education.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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