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Investigation of Factors Influencing Turkey's Pisa 2006 Science Achievement with Structural Equation Modelling*

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Abstract

This study aims, in line with PISA (Programmes for International Students' Achievement Evaluation) 2006, at constructing a structural equation model between variables considered to be associated with 15 year old Turkish students' science achievement scores and their responses to students questionnaire. In this sense, this is a relational research study. In data analysis, having identified the observed variables and the covered variables, the variables thought to predict science achievement and the relations holding between them were determined; and thus the extent to which the recommended pattern of relations was compatible with the real data was shown. On examining the structural equation modeling closely, it was found that the variable predicting students' science achievement best and the most significant factor determining achievement was "time". The other factors predictive of science achievement were found to be "the environment", "education" and "attitudes", respectively.

Key Words

PISA 2006, Structural Equation Modeling, Science Achievement.

International students' comparison projects such as TIMSS, PIRLS and PISA are non-competitive projects for participating countries to evaluate their system of education and to pursue the development of students' knowledge and skills in the fields of mathematics, science, and reading by years. What is expected of the countries, based on the results, is to realize the necessary reforms throughout the country, and to follow up the effects of these reforms by ensuring participation to the aforementioned projects. The comparative information provided by PISA gives the countries the opportunity to have an extensive evaluation of the extent to which their 15 year-old students are prepared to life (Organization for Economic Co-operation and Development [OECD], 2003).

Our country participated in the PISA activities of the Organization for Economic Cooperation and Development (OECD), of which Turkey is the charter member, in 2003. In each PISA project, which is applied every three months, a topic field is emphasized. The first PISA project was applied in the year 2000, and reading skills were emphasized. Mathematics literacy was emphasized in the second application in 2003 whereas science was emphasized in the latest application in 2006. PISA 2006 project was a project handling not only stu-

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dents' knowledge and skills in science but also their attitudes towards science (Milli Eğitim Bakanlığı [MEB], 2005).

In today's technologically advanced societies, comprehension of basic scientific concepts and theories, and the ability to construct and solve scientific problems has never been this important. In spite of this, in the last 15 years, there has been a visible decline in the number of students who study science and technology at universities in some of the OECD countries. This has various reasons. However, some researchers contend that along with science and science education curricula, students' attitude toward science may be playing a crucial role in this case (OECD, 2006).PISA 2006 is a project that evaluates not only the science knowledge and skills of students but also their attitude towards science.

In PISA 2009 science literacy field, among the countries who participated, Finland, just as it was in 2006, was the one with the highest average achievement score with its 554. Among the OECD countries, Finland was again the most successful country while the average score of Turkey was 454. With this score, Turkey was at 42. among the countries which participated in the project, and at 31 among the OECD countries. When the results of 2006 and 2009 PISA evaluation were compared, it was stated that Turkey had a 30 point increase from the 2006 PISA application in which the predominant field was science literacy to 2009. It was determined that there was an increase in the achievement of students in the field of science literacy in 9 countries out of the 57 which participated in both 2006 and 2009 PISA applications (MEB, 2010).

Several studies have been carried out in order to determine the factors affecting especially the academic achievements of students. These studies put forth that these factors have various dimensions. Among these factors, the number of students in a class (Boozer & Rouse, 2001), the quality of the teacher (Darling- Hammond, 2000), the motivation of students, the teachers self-sufficiency perception, and the attitudes of students towards learning are the ones that come to the fore (cited in Altun & Çakan, 2008). In her study, Yılmaz (2009), on the other hand, stated that many of the studies that examine the relationship between standard test scores and the variants related to students and schools have been carried out in developed countries, and thus generalizing these results to the developing countries would result in a faulty evaluation.

In line with PISA (Programmes for International Students' Achievement Evaluation) 2006, this study aims at constructing a structural equation model between variables considered to be associated with 15 year old Turkish students' science achievement scores and their responses to students questionnaire. The questionnaires performed in PISA exams are of great importance in determining factors influential over students' academic achievements. Being able to determine factors influencing our students' academic achievement, and allocating a place to modelling work between achievement scores and students questionnaire information specifies significant results.

Problem Statement

What is the general structural equation model accounting for the relations between the variables which determine 15-year old students' attitudes towards their parents' educational status, educational environment, learning time and science and students' achievement scores in science in PISA in Turkey?

Method

Type of Study

Since the results of the questionnaire conducted with 15-year old students in Turkey in line with the Programme for International Students' Achievement Evaluation (PISA) as well as correlations between their levels of achievement in the field of science studies are analyzed in this research, it is a relational study. Relational review model is a research model aiming to determine the existence and/or extent of simultaneous change between two or more variables (Karasar, 2010). A structural equation model was formed in the research by using the paraphrasing and confirmatory factor analyses. A structural equation model is a comprehensive statistical approach employed in testing the causal relations between measured and covered variables. Structural equation model connects the predictive structural relations holding between the variables in the regression model to the covered factor structures in the factor analysis through a comprehensive analysis (Sümer, 2000). In this respect this study also reveals the extent of relations between variables.

Sample

The research population is represented by 15 year old students receiving education in Turkey. The research sample, on the other hand, is composed of

4942 students randomly selected from 160 schools on the basis of stratification according to regions and school types from 7 geographical regions and 51 provinces where PISA is implemented.

Instrument

The data of the research were obtained via the internet through the data files of PISA 2006 in the PISA database of the Ministry of Education, Educational Research and Development Board. By using this rather extensive database, the variants used within the context of the research were re-codified by using code books, and data were organized. In the PISA evaluations, basically achievement tests, student and school questionnaires were used. In addition to this, optional questionnaire can also be used. The scope of this study was limited to the science achievement test and student questionnaire used in the PISA 2006 exam. In the PISA achievement test, various different question types are used such as multiple choice questions, complex multiple choice questions, open ended, and closed-ended questions. The questions asked in the exam consist of units that include textual material or graphics that students may come across with (MEB, 2009).

Data Analysis

In data analysis, initially the questions in the questionnaire were determined through basic components paraphrasing factors analysis so as to determine the factors influential over science achievement. Factor Analysis is a frequently used method, especially in social sciences, educational sciences, medicine, psychology and sociology, which enables to define a factor under a new name by grouping certain units that are unrelated to one another but may be useful in explaining a phenomenon (Özdamar, 2002). Prior to the analysis of the data, reverse coding was observed in some data and the data were rearranged by the researcher through recoding, and the data were checked for suitability for factors analysis via Kaiser- Meyer- Olkin (KMO) coefficient in addition to Barlett Sphericity test. The factor loads of the questions formed for this purpose and the specific values of the factors were then studied on SSPS 15.0 package program. Rather than considering all the survey questions, only those with the most factor load were included in the study. Not all of the questions in the questionnaire were taken into consideration in the research, and only those questions with the most factor load were included in the research. The most significant criterion here was use of at least three questions for each dimension (Schumacher & Lomax, 1996). The indices formed by considering factors analysis were specified as variables thought to predict science achievement. Utilizing the observed variables which were determined with factors analysis and the covered variables predicted by those observed variables, structural equation modelling was formed in this research. LISREAL 8.7 program was employed in constructing the model. With the help of this program, the data were cleared using the "listwise" method in correlation matrices that were formed to test different models. Due to the fact that work was done on PISA data and that the variables in the research were sequenced and categorical, Robust Maximum likelihood method beside Asimtotic Covariance Matrix were used.

Kline (2005, p. 197) stated that when some of the variants are sequential while some of them are continuous it is appropriate to use the Asymptotic Covariance Matrix, and that when all of the variants are sequential it is appropriate to use the Asymptotic Correlation Matrix. Because the research was performed through the PISA data and because the variants in the questionnaire were all sequential and categorical, in this study the Robust Maximum Likelihood Method and Asymptotic Covariance Matrix were used. In determining to what extent the suggested relationships patterns in the research are compatible with the real data, the square fitness test ($\chi 2$) recommended by Jöreskog and Sörbom (1993), Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (S-RMR), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), and Comparative Fit Index (CFI), Non-Normed Fit Index (NNFI) values, indicated by Cheng (2001), were used.

Results

Indices formed by considering factors analysis were determined as variables that were thought to predict science achievement in this study. Questions with the highest factor load were included in the study, and covered variables were described for LISREL model.

Having determined observed variables and covered variables, variables that were thought to predict science achievement as well as relations between them were determined by using the structural equation model, and then the extent to which the recom-

mended relations block was compatible with the real data was determined. On examining the compatibility index results of the constructed equation model, the model - data compatibility was found to be quite high. Chi- square value, one of the compatibility statistics, was found significant. As is pointed out by McDonald and Moon-Ho (2002), Schermelleh-Engel, Moosbrugger and Müller (2003), and Thompson (2009), due to the fact that Chi-square value is sensitive to the size of the sample, it is almost always significant with very big samples in particular. Therefore, it is recommended that the Chi-square value should be divided into the freedom degree, and the resultant coefficient should be used. Yet, in some cases this coefficient value is found to be too big. Although this is an undesirable case, it is known that Chi-square and freedom degree are affected by sample size (Fasinger, 1987). Jöreskog and Sörbom (1993), Marsh and Hocevar (1988) point out that the case in which the calculated GFI and AGFI values are higher than 0.90 and RMR and RMSEA values are lower than 0.05 displays perfect model-data compatibility. The GFI compatibility index value (0.87) and AGFI compatibility index value (0.85) of the model constructed in this study show that a sufficient level of compatibility is available for model-data compatibility. Moreover, the calculated NFI (0.99), SRMR (0.084), and RMSEA (0.043)) values demonstrate that a perfect compatibility holds between the model and the data. The CFI (0.99) and the IFI (0.99) values found through analyses, on the other hand, show that model-data compatibility is perfect.

On examining the compatibility indices results for the structural equation modelling constructed in the research, the compatibility between the model and the data was found to be quite high- a result which demonstrated that the indices sufficiently accounted for the correlations holding between the model variables. Modification indices were examined and correlations between some variables were relieved in developing the model. For this purpose, the correlations between the desk and the computer were relieved, and the model was re-tested. Thus, it was found that chi square value dropped from 1830.79 to 1577.79 whereas RMSEA value dropped from 0.046 to 0.043 prior to the modification.

On examining the structural equation modelling, it was seen that the variable best predicting students' achievement in science and the factor determining achievement was "time". A linear positive correlation was found between the time allocated to learning and science achievement, where the relation coefficient value was found to be γ=0,32. As pointed out by Kubitschek, Hallinan, Arnett and Galipeau, (2005) in their work, where they researched modifications to high school programmes and the effects of wasted time on success, time is an important source for a school. A group of researches demonstrates that an increase in time devoted to education leads to an increase in success (Dreeben & Gamoran, 1986; Karweit & Slavin, 1981; Wiley, 1976). Zeith and Cool (1992) also conclude that time allocated to learning has an important effect on students' academic achievement. It has become evident that second most important factor determining success at science is the "environment", and that students' having a room for studying, a desk, a computer, a computer program, and an internet connection of their own contributes to their success at science in a positive way. Relation coefficient value is γ=0,22 here. In the work by Taningco and Pachon (2008); Schmitt, Sacco, Ramey, Ramey and Chan, (1999), it is suggested that a high level of parents' education affects students' academic achievement in a positive way; which supports the conclusions of the current research. A positive, linear relation which was not high was determined between science achievement and the "attitude" towards science in the model. The relation coefficient value was γ=0,12. In conclusion, achievement in science rises in parallel to an increase in positive attitudes towards science. However, it must not be forgotten that the level of relations between them is not very high.

On examining the regression equation of the covered variables predicted by variables that were included in the structural equation model (that is, the determined observed variables), the statement coefficient value of the model was found as (R^2) 0.36.

SCIENCE= 0.22*Education +0.23*Environment + 0.13*Attitude+ 0.32*Time, Error var.= 0.64 , R^2 = 0.36

It is evident that the four predictor variables that were included in the regression equation account for 36% of the overall variance of the science achievement score, which is the dependent variable. As can be seen also in the regression equation, the variable best predicting students' science achievement is the variable of "time" devoted to learning.

Discussion

This research aims at constructing a structural equation model, in line with PISA 2006, between variables considered to be associated with 15 year

old Turkish students' science achievement scores and their responses to students' questionnaire. On examining the compatibility index results of the constructed equation model, the model - data compatibility was found to be quite high. Considering all the values for model-data compatibility, it becomes clear that the compatibility of the model constructed is quite high. This is a result which demonstrates that the indices sufficiently account for the correlations holding between the model variables. On examining the structural equation modelling, it was seen that the variable best predicting students' achievement in science and the factor determining achievement was "time". A linear positive correlation was found between the time allocated to learning and science achievement. As is pointed out by Kubitschek et al. (2005) in their work on modifications to high school syllabi and the influence of wasted time over achievement, time is an important source for schools. Research studies have made it clear that an increase in time allocated to education also affects success (Dreeben & Gamoran, 1986; Karweit & Slavin, 1981; Wiley, 1976). It is also pointed out that time is not sufficient on its own for learning and that several factors such as the student's individual ability, the teacher's quality in teaching, and school organization are also influential on learning. Zeith and Cool (1992) also conclude that time allocated to learning has an important impact on students' academic achievement. Considering the fact that variable best predicting science achievement is "time", it might be recommended that more time should be allocated to science courses and topic related with science so as to improve students' science achievement. It has become evident that second most important factor determining success at science is the "environment", and that students' having a room for studying, a desk, a computer, a computer program, and an internet connection of their own contributes to their success at science in a positive way. Considering the fact that second most important factor determining success at science is the "environment, it becomes evident that enriching the educational environment in students' homes is influential over their achievement.

It might be recommended that the use of materials such as computers especially – an effective way of having access to knowledge, computer program and the internet should be made widespread so that students reach easily. It was found that third most important factor determining science achievement was "education", which meant that an increase in parents' level of education contributed positive contributions to students' science achievement; that is to say, students with parents of university education or further education displayed higher achievement in science and thus a positive correlation was found between the two. In the work by Taningco and Pachon (2008); Schmitt et al. (1999), it is suggested that a high level of parents' education affects students' academic achievement in a positive way; which supports the conclusions of the current research. It was found that an increase in the level of parents' education made positive contributions to students' science achievement. Therefore, it might be recommended that activities should be done to raise parents' level of education. Besides, school-parents cooperation should be established and seminars should be held. A positive, linear relation was determined between science achievement and the "attitude" towards science in the model. In other words, it was found that science achievement increased in parallel to the increase in positive attitudes towards science. Thus, it might be recommended that application work in which students enjoy problem solving related with science should be performed. The fact that Oliver and Simpson (1988) note a strong correlation between science achievement motivation and attitudes towards science studies supports the findings of this research. It may be recommended that application activities in which students enjoy problem solving about science should be included. In a study conducted by Erbaş (2005), where science literacy and the related factors are analyzed considering the PISA data, it was pointed out that positive correlations were available between teacher-student interaction, the number of books at home, participation in pre-school education, basic computer knowledge, and science literacy whereas improvement courses organized by school, and homework assigned had positive effects on attitudes towards school but had no effects on students' science literacy skills. Özer (2009), on the other hand, in a modelling study evaluating 15 year old group's science and mathematics achievement based on the PISA data, pointed out that time allocated to learning influenced achievement in science and mathematics in a positive way, which is supportive of our findings. It was pointed out that the variable of family properties had positive influences in students' science and mathematics achievement, while a positive relation held between the variable of students' having educational material and their achievement in science but it did not have relations with mathematics achievement. In their

research Ceylan and Berberoğlu (2007) made an attempt at displaying the factors related with science achievement by using the data obtained from Turkish students taking part in the Third International Science and Mathematics Activity. The findings demonstrated that there were negative correlations between students' perception of failure, student-centered activities, and between students' attitudes towards science studies and their achievement in science; yet positive correlations were found between teacher-centered activities and students' achievement in science. Based on their findings, they recommended that Turkish system of education should be revised in terms of several points on the basis of the renewed curricula.

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