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Araştırma Makalesi / Research Article

The Link between Structural Quality Indicators in Pre-primary and PISA Science Literacy Skills: A Cross-Country Comparison

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Abstract – The main aim of this study was to investigate the profile of countries included to the study based on their structural quality indicators and make a comparison across distinct countries to investigate the relationship between eight quality indicators in pre-primary education and children's subsequent science competency in the Program for International Student Assessment (PISA) between 2000-2015 years. The cross-national indicators that were used were obtained from previous records, including public and private expenditure, pupil-teacher ratio, enrollment rate, duration, age of beginning in pre-primary education, individual countries' adult literacy rates, and income per capita. The relational survey model which is one of the quantitative research was utilized for the current study. The results showed that the relationship between public expenditure, pupil-teacher ratio, income per capita, adult literacy rate and children's subsequent science performance on the PISA were positively statistically significant at a country-level. One of the important implications of the current study is that countries that spend less (which include Turkey) should plan a detailed pre-primary expenditure agenda for the public sector and raise their current level of public spending.

Key words: Cross-country comparison, PISA, pre-primary education, quality indicators in pre-primary, science literacy skills

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Özet

Giriş

İnsanların tamamının potansiyeli, erken çocukluk dönemindeki beyinsel fonksiyonlarının hızlı gelişimi nedeniyle, özellikle bu dönemdeki eğitim fırsatları ve deneyimleri ile şekillenmektedir (Shonkoff ve Phillips, 2000). Günümüzde farklı eğitim ihtiyaçları, çocukların eğitiminde çok-işlevli gereksinimleri karşılamanın, tüm uluslar için büyük önem taşıdığı anlamına gelmektedir. Günümüzün erken çocukluk eğitimi programları, akademik açıdan daha nitelikli nesiller yetiştirmeyi hedeflemekte, fen, matematik ve dil gibi çeşitli öğrenme alanlarında daha gelişmiş imkanlar sunmaktadır. Erken çocukluk dönemi öğrenme ortamı; çocukların okul öncesi eğitime başlama yaşı, anaokulu sınıflarındaki öğrenci-öğretmen oranı, ebeveyn okur-yazarlığı, ailenin ekonomik koşulları ve eğitim harcamaları gibi, çeşitli değişkenleri kapsamaktadır (Carneiro, Meghir, & Parey, 2013). Çeşitli çalışmalarda, bu değişkenlerden her birinin çocukların akademik performansı üzerindeki etkileri araştırılmıştır (Blatchford, 2004; Iacovaou, 2001) ve çalışmaların tümünde erken çocukluk dönemi eğitiminde yüksek-kaliteli bir öğrenme ortamının gerekliliği ve önemi gösterilmiştir (Watters ve arkadaşları, 2001). Kapsamlı ve giderek artan bir alanyazın, bazı sosyo-ekonomik göstergelerin çocukların akademik başarıları üzerindeki etkinliğini araştırmaktadır. Öğrenme ortamlarının ve çocukların akademik performanslarının değerlendirilmesi bütün bir süreç olarak görülmelidir, bu sebeptendir ki Avrupa ülkelerinin çoğunluğu erken çocukluk eğitimindeki başarılarını belirlemek için ülkeler arası karşılaştırmalara daha fazla önem vermektedir (Sahlberg, 2018). Aynı nedenle, erken çocukluk eğitimi sistemlerinin etkinliğinin değerlendirilmesi ve karşılaştırılması için ve son yıllardaki farklı öğrenme alanlarındaki başarıların ölçülmesi için en popüler yöntemlerinden birisi (Birchler ve Michaelowa, 2016) Uluslararası Öğrenci Değerlendirme Programı (PISA) nın kullanılması olmuştur (OECD, 2007). Ekonomik İşbirliği ve Kalkınma Örgütüne göre (OECD, 2007), PISA' da fen okur-yazarlığı değerlendirilmesi, genel fen başarı puanından farklı olarak, insanların bilimsel bilgilerini temel alan bilimsel düşünme yeteneklerinin belirlenmesi ile ilgilidir.

Amaç

Erken çocukluk eğitiminin yapısal özelliklerini uluslararası düzeyde incelemek, ulusların erken çocukluk eğitim sistemleri için bir temel oluşturma yöntemidir. Bu nedenle, bu çalışma çocukların fen okur-yazarlığı konusundaki yeterliliklerini, okul ve ev ortamlarının nasıl etkilediklerine dair görüşlerimizi geliştirmek için sosyal sermaye teorisine

dayandırılmıştır. Bu nedenle, bu çalışmada, yüksek-kaliteli erken eğitim hedefine ulaşmak için kurulması gereken eğitim sistemlerini ve çocukların fen okur-yazarlığındaki akademik performanslarını belirleyen faktörlerin belirlenmesi için PISA verileri kullanılmıştır.

Aşağıdaki gösterildiği gibi iki temel araştırma sorusu oluşturulmuştur:

1. 33 OECD üyesi olan ve OECD üyesi olmayan ülkelerdeki bazı yapısal göstergelerin, 2015 PISA performanslarına karşılık gelen profilleri nasıldır? (okul öncesi eğitimde kamusal ve özel harcamalar, yetişkin okur-yazarlık oranı, *kişi başına* gelir, okul öncesi eğitime kaydolma oranı, öğrenci-öğretmen oranı, okul öncesi eğitime başlama yaşı ve okul öncesi eğitimin süresi)
2. 33 OECD üyesi olan ve OECD üyesi olmayan ülkelerdeki, okul öncesi eğitim değişkenleri (okul öncesi eğitime kaydolma oranı, okul öncesi öğrenci-öğretmen oranı, okul öncesi eğitime başlama yaşı ve okul öncesi eğitim süresi), hükümet göstergeleri (özel ve kamu harcamaları) ve sosyo-ekonomik değişkenler (yetişkin okur-yazarlığı oranı ve gayri safi milli gelir), bu ülkelerin 2000-2015 yılları arasında PISA fen okur-yazarlığındaki performanslarını ne ölçüde tahmin etmektedir?

Metodoloji

Bu korelasyon çalışmasında, toplam 33 OECD üyesi olan ve OECD üyesi olmayan ülkelerin 2000, 2003, 2006, 2009, 2012 ve 2015 PISA fen okur-yazarlığı puanları kullanarak, ülke-düzeyinde erken çocukluk eğitimi ve sosyo-ekonomik koşullar ile fen okur-yazarlığı performansları arasındaki ilişki araştırılmıştır. Ülkeler arası karşılaştırma yapılırken, 15 yıllık veri (2000-2015 PISA yılları arası), 8 değişken (okul öncesi eğitimdeki kamusal ve özel harcamalar, öğrenci-öğretmen oranı, okul öncesi eğitime kaydolma oranı, okul öncesi eğitim süresi, okul öncesi eğitime başlama yaşı, herbir ülkedeki yetişkin okur-yazarlığı oranı ve kişi başına düşen milli gelir) kullanılarak, 33 ülkenin verisi çoklu regresyon analizi ile analiz edilmiştir. Kullanılan veriler, araştırmacıların güvenilirlikle veri setleri oluşturmalarına olanak sağlayan ve bir çok farklı sayısal göstergelere erişim sağlayan Dünya Bankası, UNESCO ve OECD'nin çeşitli istatistik veri tabanlarından alınmıştır.

Bulgular, Tartışma ve Sonuç

Araştırma sorusunu araştırmak için panel verileri analizi 33 ülke ve 8 değişken ile yapılmıştır. Panel veri setinde, zaman içinde gözlenen bu 8 değişken için bir zaman serisi oluşturulmuştur. PISA fen okur-yazarlık puanları ilgili yıllara ait okul öncesi eğitim ve sosyoekonomik göstergeler ile eşleştirilmiştir. Analizlere göre, bulgular diğer değişkenler sabit tutulduğunda, kamu harcamalarında ($\beta = 0.26$) yüzde bir puanlık bir artışın, tüm

ülkelerdeki PISA fen okur-yazarlık puanında 62.86 puanlık bir artışa yol açtığını göstermektedir. Bu değer, ülke-düzeyinde sonraki akademik başarı için en yüksek beta katsayısıdır; ve bu değişkenin modeldeki diğer tüm değişkenler tarafından açıklanan varyans hesaba katıldığında, bağımlı değişkeni açıklamak için en güçlü katkıyı sağladığını göstermektedir. Ayrıca, yetişkin okur-yazarlık oranı (β = 0,41), kişi başına düşen GSYİH (β = 0,43) ve öğrenci öğretmen oranları (β = -0,26) göstergeleri, PISA puanları üzerinde önemli bir etkiye sahip olmuştur. Buna karşılık, okul öncesi eğitimde özel harcamalar, okul öncesi eğitime kayıt oranı, okul öncesi eğitime başlama yaşı ve okul öncesi eğitim süresinin istatistiksel olarak anlamlı olmadıkları bulunmuştur.

Ülkeler-arası mevcut analizlerin sonuçları, kamu harcamalarının ülkelerin PISA performansında önemli bir rol oynadığını açıkça göstermektedir ve Türkiye, değerlendirilen tüm ülkelerin kamu harcamalarının en azını harcamaktadır. Sonuçların, okul öncesi eğitimde kamu harcamalarının önemini göstermeye yardımcı olacağı ümit edilmektedir ve okul öncesi eğitim için daha az harcama yapan ülkelerin mevcut kamu harcamalarını arttırmaları ve okul öncesi eğitim için detaylı bir kamu sektörü harcama ajandasını geliştirmeleri önerilmektedir. Ülke düzeyinde yapılan analizler, okul öncesi eğitime kaydolma oranının öğrencilerin daha sonraki fen okur-yazarlığı performanslarında istatistiksel olarak anlamlı bir değişken olmadığını gösterse de, okullaşma oranının yüksek olduğu ülkeler PISA da Türkiye'ye göre daha iyi bir performans göstermektedirler (OECD, 2015). Bu nedenle, yüksek-kaliteli erken çocukluk eğitimi sağlanması, çocukların daha sonraki okur-yazarlık düzeyleri üzerinde önemli bir etkiye sahip olabilir; böylelikle, ebeveynlerin erken eğitimin önemi hakkındaki farkındalığını artırarak, erken eğitim farkındalığı yaratmak çok önemlidir. Ayrıca, ülkelerin Milli Eğitim Bakanlıkları, erken eğitime katılmayan küçük çocukların izini sürecek bir sistem geliştirebilirler. Bu tür önlemler, erken çocukluk eğitimi programlarına kayıt oranlarının arttırılmasına yardımcı olabilir.

Erken Çocukluk Eğitimi Yapısal Kalite Göstergeleri ve PISA Fen Okur-yazarlık Becerileri Arasındaki İlişki: Ülkeler-Arası Karşılaştırma

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Özet– Bu çalışmanın temel amacı, farklı ülkelerde erken çocukluk eğitimindeki çeşitli kalite göstergeleriyle, çocukların sonraki Uluslararası Öğrenci Değerlendirme Programı (PISA) daki Fen okur-yazarlık becerileri arasındaki ilişkiyi araştırmak ve ülkeler-arası bir karşılaştırma yapmaktır. Kullanılan ülkeler-arası göstergeler; okul öncesi eğitimdeki kamusal ve özel harcamalar, öğrenci-öğretmen oranı, kaydolma oranı, okul öncesi eğitim süresi, okul öncesi eğitime başlama yaşı, yetişkin okur-yazarlığı oranı ve kişi başına düşen milli gelir dahil olmak üzere, daha önceki yıllarda toplanan verilerden elde edilmiştir. Bulgular; kamusal harcamalar, öğrenci-öğretmen oranı, kişi başına düşen milli gelir, yetişkin okur-yazarlık oranı ve çocukların sonraki PISA değerlendirmesindeki fen okur-yazarlık performansları arasındaki ilişkilerin ülkeler-düzeyinde pozitif yönde istatistiksel olarak anlamlı olduğunu göstermiştir. Mevcut çalışmanın önemli çıkarımlarından birisi; (Türkiye dahil) diğerlerine kıyasla okul öncesi eğitiminde daha az kamu harcaması yapan ülkelerin, harcamalarına ilişkin mevcut harcama seviyelerini yükseltmesi ve kamu sektörü için daha detaylı bir okul öncesi harcama ajandası planlaması gerektiğidir.

Anahtar kelimeler: Ülkeler-arası karşılaştırma, PISA, okul öncesi eğitim, okul öncesi kalite göstergeleri, fen okur-yazarlık becerileri

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Sorumlu yazar: Elif BULDU, Ankara, Türkiye.

[*] Bu çalışma, "Erken çocukluk eğitiminde kalite göstergelerinin etkililiğinin sonraki fen okur yazarlık becerisi ile ilişkisinin ülkeler arası kıyaslaması ve Türkiye özelinde bir analiz" isimli yüksek lisans tez çalışmasının bir parçasından oluşturulmuştur.

Introduction

Innovations in science and technology now develop rapidly, so nations require scientifically literate citizens, who are creative, decision-makers, and problem-solvers, and who have an understanding of scientific and technological innovations (National Research Council [NRC], 1996). According to NRC (1996), which is guideline for science education in the United State of America, scientific literacy is the ability to ask, find, or determine the answers to meet an individual's curiosity, and is derived from everyday experiences. As scientifically literate individuals can evaluate the quality of scientific information based on sources and methods, they can use their advanced skills to understand the world around them. Such qualities enable nations to have a more scientifically literate population, and therefore education is one of the most important determinants of individuals' capacities (Koballa, Kemp & Evans, 1997; McFarlane, 2013).

The potential of all human beings is shaped by their educational opportunities and experiences, particularly during the early childhood period, because of rapid development in brain function during this time (Shonkoff & Philips, 2000). The different educational needs nowadays mean that it is of great importance for all nations that children's education meets multi-functional requirements. For instance, a number of governments recognize the importance of investing in children's education during the early developmental cycle, to improve sustainable growth and economic productivity (World Bank, 2013). Several studies have highlighted the fact that high-quality preschool education has a dramatic effect on the school readiness of young children and on their subsequent level of success at school (Claessens & Engel, 2013; Shonkoff & Phillips, 2000). Thus, the provision of high-quality early educational experiences helps to close the gap in achievement between children from high- and low-income families, and again boosts the potential to learn (Engle et al., 2011).

As early education has been approved as an educational building block (Bredekamp, 2011), various nations have revised their early childhood education programs to meet expectations with regard to children's academic competency. Aiming for academically better-qualified generations, today's early childhood education programs offer improved preparation in a variety of learning areas, such as science, mathematics, and language. In the same way, in order to raise scientifically literate generations, science is a learning area that has attracted the attention of researchers with regard to examining the effect of early childhood education. One of the important contributions of an early science education is to provide children with the ability to make connections between facts and solutions by teaching science knowledge

during their earliest years (Saçkes, Trundle, Bell, & O' Connell, 2011). Similarly, teaching science knowledge to young children helps to develop scientific thinking skills and positive attitudes toward science throughout their subsequent school life (NRC, 1996). In the view of all that the provision of a rich learning environment, experiences, and opportunities in children's science education will therefore lead to more desirable learning outcomes. However, a number of factors in learning environments can affect young children's science learning and achievement; diversity of educational conditions in early childhood settings and children's family backgrounds are two important factors in this respect (Pianta et al., 2002). The results of previous studies have also highlighted that there is a close relationship between children's science learning environment and their later academic achievement in that area (Buldu, Buldu, & Buldu, 2014, Saçkes et al., 2011; Yi, 2006).

The early childhood learning environment encompasses many different variables, including the age at which children begin pre-primary education, the pupil-teacher ratio in kindergarten classes, parental literacy, a family's economic circumstances, and educational expenditure (Carneiro, Meghir, & Parey, 2013). Several different studies have investigated the effectiveness of each of these variables on children's academic performance (Blatchford, 2004; Iacovaou, 2001), and they have all demonstrated the necessity for, and importance of, a high-quality science-learning environment in early childhood education (Watters, Diezmann, Grieshaber, & Davis, 2001). A large and growing body of literature has investigated the effectiveness of some socio-economic indictors on children's academic achievement (Hanushek & Woessmann, 2016). Some of these indicators are investing in children's education and family characteristics in terms of income and educational attainment. For instance, the study that conducted by Macours, Schady and Vakıs, (2012) has shown that spending the cash money has significant effect on children's cognitive and educational outcomes. This view is supported by Qian and Smyth (2011). They argue that there is a close relationship between parents' educational expenditure and students' educational attainment because household educational expenditure is related with family income. Addition to family income, parents' education level is seen as a determinant of academic success by Erola, Jalonen and Lehti (2016). They argue that parental income has no effect independent of parental education. Furthermore, a considerable amount of literature has been published to reveal the relationship between children's academic achievement and educational indicators in early childhood education. In a study which set out to determine the effect of pupil-teacher ratio in early childhood classrooms on children's achievement, Blatchford et al. (2011) found that smaller classes have positive effect on children's academic achievement. To determine

the relationship between receiving early childhood education and children's academic achievement, Jacinta and Rotich (2015) found that attending early childhood education enabled children to fluent in reading and mathematics in their primary school years.

Nevertheless, it is important to note that it is fairly challenging to assess the achievement of well-established educational indicators while simultaneously attempting to extend early education to all children (Britto, Yoshikawa, & Boller, 2011). For example, in France, the government financially supports pre-primary education from the age of three years (Jacobson, 2001), which ensures that parents voluntarily put their children into kindergarten. To this end, it is important to examine which social and environmental factors and indicators help to improve children's potential in science learning, and there is a pressing need for nations to determine which of these result in a successful outcome in science literacy. Therefore, the evaluation of learning environments and the assessment of children's academic performance can be viewed as an entire process, the majority of European countries are paying increasing attention to cross-national comparisons to determine their success in early childhood education (Sahlberg, 2018). For the same reason, one of the most popular methods of assessing and comparing the effectiveness of early childhood education systems, and success in different learning areas in recent years, has been the use of international assessments (Birchler & Michaelowa, 2016), one of which is the Program for International Student Assessment (PISA). The main purpose of the PISA is to examine students' abilities to meet real-life challenges in different learning areas, such as science, mathematics, and reading. According to the Organization for Economic Co-operation and Development (OECD, 2007), unlike the general science achievement score, the assessment of scientific literacy in PISA is related to determining people's ability to think scientifically, based on their scientific knowledge. The results that are obtained from the PISA science literacy domain can supply nations with feedback in evaluating the quality and the efficiency of their school system in providing students with these literacy skills in science. Therefore, PISA is an effective way to estimate a nation's educational production in an international arena (Saatçioğlu & Gülleroğlu, 2017). Therefore, this result of the study is important for countries whose performances were under the OECD average, like Turkey, Mexico and other developing countries. One of the main reasons for the selection of the science literacy domain in the current study is that high level thinking is increasingly important in today's world. On the other hand, there was no students at the highest level (Level 6) of science literacy domain in Turkey (Şirin & Vatanartıran, 2014) and also there is a strong decrease in the science

literacy domain made in 2015 PISA compared to previous years. From this point of view, the results of the study will enable us to see which quality indicators are needed to be improved while providing more effective education policies for students. Moreover, the importance of pre-primary education and the PISA performance of countries are limited to a number of studies (Şirin & Vatanartıran, 2014). Based on this, the current study examines many factors that affect the quality of pre-primary education, and these factors are important in terms of its longitudinal explanation that PISA brings success and failure for science literacy. Considering all these reasons, it can be said that the effectiveness of pre-primary education will contribute to the literature on quality indicators in pre-primary education in terms of examining the science literacy performances of the low and middle-income countries in the PISA assessment.

Examining the structural characteristics of nations' early childhood education at an international level is a way of providing a foundation for early childhood education systems. Therefore, the current study was grounded in social capital theory to improve our understanding of how school and home environments affect children's competency in science literacy. Social capital theory is primarily concerned with social and economic development, and its interaction between individual development and government (Alacacı & Erbaş, 2010). Therefore, the present study used PISA data to identify the education systems that must be established in order to achieve high-quality early education and the factors that determine children's later academic performance in scientific literacy.

Two main research questions were generated, as follows:

1. How do the profiles of 33 OECD and non-OECD countries on some structural indicators (public and private expenditure on pre-primary education, adult literacy rate, income *per capita*, enrollment rate in pre-primary education, pupil-teacher ratio, age of beginning pre-primary education, and duration of pre-primary education) corresponded to the 2015 PISA performance?

2. To what extent did the pre-primary education variables (primary enrollment rate, pupil-teacher ratio in pre-primary education, age of beginning pre-primary education, and duration of pre-primary education), indicators of governance (private and public expenditure), and socio-economic variables (adult literacy rate and individual income) of 33 OECD and non-OECD countries predict those countries' performances in PISA science literacy between 2000 and 2015?

Method

This study embraced relational survey model, which is one of the quantitative research approaches and investigated the association of cross-country indicators of early childhood education and socio-economic conditions on science literacy performance, using the 2000, 2003, 2006, 2009, 2012, and 2015 PISA science scores of 33 OECD and non-OECD countries. In the cross-county comparison, 15-years data set (between 2000-2015 PISA), 8 variables (primary enrollment rate, pupil-teacher ratio in pre-primary education, age of beginning pre-primary education, and duration of pre-primary education, private and public expenditure, adult literacy rate and individual income) and 33 countries data were analyzed through multiple regression analysis. In this analysis, panel data set was used to organize the data from past to present and to represent the indicators of each country in different years.

The countries, namely, Australia, Austria, Argentina, Azerbaijan, Brazil, Bulgaria, Canada, the Czech Republic, Denmark, Estonia, France, Germany, Hungary, Iceland, Israel, Italy, Japan, Kazakhstan, South Korea, Mexico, New Zealand, Peru, Poland, Portugal, Romania, Russia, Spain, Sweden, Thailand, Finland, Turkey, the United Kingdom, and the United States, were selected from different parts of the world in order to represent distinct early childhood education systems and country profiles. The use of these scores, from distinct education systems, enabled the investigation of some quality indicators from pre-primary education systems which include kindergarten, preschool and nursery education programs and individual children's socio-economic status in order to identify the determinants of subsequent science literacy skills. In doing so, the aim was to reveal the significance level of each indicator via multiple regression analysis.

The Source of Data And Preparation

The data used came from various statistical warehouses of the World Bank, United Nations Educational, Scientific and Cultural Organization (UNESCO), and Organization for Economic Co-operation and Development (OECD), which provide access to a large number of numerical indicators, enabling investigators to establish datasets confidently. After data was obtained for the study, public and private expenditure, pupil-teacher ratio, gross enrolment rate, duration of pre-primary education, per capita as a Gross Domestic Product (GDP), and adult literacy rate were centralized as predictor variables. The PISA science literacy score of countries was selected as an outcome variable.

Weighted data from PISA 2000, 2003, 2006, 2009, 2012, and 2015 was used as a dependent variable for the regression analysis in the current study. Because countries' PISA scores were weighted and ready for statistical analysis, the cross-country comparison can be conducted with countries' PISA scores with any other statistical procedure (OECD, 2009). Independent variables also were retrieved from the World Bank and UNESCO statistics of which accesses open to public use for researchers. After the necessary data cleaning procedure, independent variables were prepared for the analysis. To analyze the data, multiple regression analysis was conducted through panel dataset because this method has more variability, less collinearity and more degrees of freedom. Addition to this, it provides an idea about the time-ordering of events.

Data Analysis

The sample employed in the current study included 33 OECD and non-OECD countries that participated in PISA assessments in 2000, 2003, 2006, 2009, 2012, and 2015. To investigate the research question, the multiple regression analysis was conducted with 33 countries and 8 variables to analyze children's prospective science performance in the PISA. By organizing data for analyzing, the panel dataset was used in which variables observed across time were organized as a time series data. Since, PISA science scores should match with pre-primary and socio-economic indicators in corresponding years, retrospective data which is nearly 10 years before PISA assessments because the selected preschool generation only take part in the PISA assessment when they get to 15 year-olds were used.

In order to match PISA scores with the right-hand side control variables, the PISA scores in year "t" were paired with the related control variable in year "t-10". This allowed the matching of observations for control variables with the same group of pupils that took the PISA test. Here, $X^{s}_{(t-10)}$ were the independent (control) variables which represent pre-primary education, including private and public expenditures as a ratio to GDP, gross enrollment rate in pre-primary education, age of beginning pre-primary education, duration of pre-primary education, and teacher-pupil ratio in pre-primary education in year *t-10*. Therefore, independent variables were selected for the years 1990-2005 which correspond to the 2000-2015 PISA assessment terms. Multiple regression analysis was used to analyze the data, in order to explain the relationship between the predictor and outcome variables. The opened form of the basic regression specification is shown below.

$$PISA_{t} = \beta_0 + \beta_1 Exp_{pub\ (t-10)} + \beta_2 Exp_{pri\ (t-10)} + \beta_3 Enroll_{pre\text{-}p\ (t-10)} + \beta_4 PTR_{pre\text{-}p\ (t-10)} + \beta_5 Dur_{(t-10)} + \beta_6 Startage_{(t-10)} + \beta_7 Income_{(t-10)} + \beta_8 Adullit\ (t\text{-}10) + \varepsilon$$

PISA science literacy scores were determined as dependent variables that were all weighted for each level of analysis, in order to conduct the multiple regression analysis. The participants are selected by using multisampling methods in PISA assessment. In a country, each student who is 15 years-old has an equal chance to participate in the PISA assessment. Since the weight of the three domains changes in every exam year, calculating means of three domains at the same level is not convenient to see a trend over time (OECD, 2009). Therefore, selecting one domain is more calculable to estimate later school achievement for the current study. To overcome the year differences between starting age to pre-primary education in different countries in corresponding data, all of the indicators were selected as a country level and decided to go back 10 years ago. Additionally, during the sample selection process for PISA assessment, non-sampling errors were greatly minimized via testing and observation (Statistics Canada, 2013). For the analysis of the data, level of significance (*p*-value) was less than 0.05 to determine statistical significance.

Statistical Assumptions And Necessary Tests for Regression Analysis

In the current study, all of the independent and dependent variables obtained from the World Bank, OECD and UNESCO databases represent countries' general conditions for each of the country. That is why the sample correlation was zero between independent variables. Also, in the current analysis, no endogenous variable was observed, and the value of *u* is zero. For this reason, the zero condition mean assumption was not violated. To check the collinearity assumption, *Correlation Coefficient Test* was conducted and the VIF values are less than 10 for each of the variables. Thus, the collinearity assumption was not violated. Furthermore, the scatter plots of regression analysis showed that the data to be perfectly normally distributed. Thus, the normality assumption is also met. Lastly, Breusch-Pagan and modified Wald tests are applied. The test results yield failure of rejection of the null hypothesis, which refers errors are homoscedastic, at 5% significance level.

Results

Cross-national Comparison of Indicators

All 33 OECD and non-OECD countries that participated in the PISA were selected using eight variables (private and public expenditures as a ratio to GDP, gross enrollment rate

in pre-primary education, starting age in pre-primary education, duration of pre-primary education and teacher-pupil ratio in pre-primary level) relate to structural quality in early childhood education and governmental factors. As the country contexts that were included are vastly different from each other, Table 1 was created to depict the profiles of the countries with regard to these quality indicators. In this table, the values reflect each country's socio-economic and educational conditions in 2005, which is the last year in the dataset and corresponds to the 2015 PISA year, and this can help to illustrate which country has maximum or minimum values within these indicators. However, some of the values in Table 1 have not been presented, due to limited data observation from different data sources. Furthermore, In the Table 1, the gross enrollment rates were over 100 % for some of the countries were analyzed. The reason of this is that gross enrollment rate includes students for all ages, which means that students exceed the official age group, like late, early and repetition enrolments (World Bank, 2017).

Table 1. Countries' Profile and Values in Selected indicators from the year of 2005 as a corresponding to 2015

Countries	Pub Exp %	Pri Exp%	Pre-Pri Enrol%	Pupil/ Teac	Starting Age	Duration in Pre-Pri	GDP	Adult Lit. %	PISAScores
Turkey	0.03	0.02	11.2	19	3	3	4595	88	425
Peru	0.30	0.10	63	24	3	3	2863	88	397
Iceland	0.67	0.24	96	6	3	3	49620	98	473
Portugal	0.35	0.00	79	15	3	3	18185	94	501
Italy	0.45	0.03	104	12	3	3	30478	99	481
Spain	0.68	0.24	118	14	3	4	25425	98	493
Russia	0.48	0.01	87	7	3	4	5337	100	487
Sweden	0.50	-	94	10	3	4	41040	99	493
Hungary	0.70	0.05	85	11	3	4	10936	99	477
Israel	0.66	0.20	94	24	3	3	20180	97	467
Bulgaria	0.65	0.10	79	11.5	3	4	3733	98	446
Kazakhstan	0.15	0.06	34	11	3	4	3771	99	-
Thailand	0.50	0.01	94	25	3	3	2689	94	421
Mexico	0.52	0.12	104	29	4	2	6910	91	416
Brazil	0.40	0.35	69	18	4	3	4739	89	401
Argentina	0.35	0.10	66	19	3	3	4740	98	475
Austria	0.42	0.13	89.7	14	3	3	37067	98	495
Australia	0.06	0.04	101	-	4	1	36113	100	510
Denmark	0.91	0.13	95	-	3	4	48590	99	502
France	0.64	0.04	117	18	3	3	34850	99	495
Korea	0.05	0.07	92	20	5	1	17551	98	516
Japan	0.09	0.12	89	29	3	3	39140	99	538
Estonia	0.36	0.00	114	7.5	3	4	16392	99	534
Finland	0.35	0.04	60	12	3	4	44200	100	531
Poland	0.52	0.14	54	17	3	4	7963	99.5	501

Table 1 Cont'd	Public Exp. %	Private Exp. %	Pre-Pri. Enroll%	Pupil/ Teacher	Starting Age	Duration of Pre-Pri.	GDP	Adult Lit.%	PISA Scores
Germany	0.42	0.18	94	12	3	3	35115	99	502
Canada	0.23	-	69	-	4	2	33110	99	528
Check Republic	0.38	0.04	115	13	3	3	12706	99	493
UK	0.34	0.03	71	21	3	2	38548	99	509
USA	0.35	0.08	63	17	3	3	44313	99	496
New Zealand	0.23	0.09	92	15	3	2	27539	100	513
Romania	0.35	0.00	71	18	3	4	4572	98	435

When Table 1 is investigated in detail, it can be observed that one of salient pre-primary education indicators was pupil-teacher ratio; this rate varied greatly, from country-to-country. For example, while being fairly low in Iceland, Estonia, and Sweden, it was very high in Mexico, Thailand, and Japan.

Some of the European Countries, such as Denmark, France, and Hungary, spent far more money on pre-primary education in terms of both public and private expenditure. In contrast, Turkey, Korea, and Japan spent significantly less on pre-primary education.

The table 1 shows that most of the European countries reached a 99% adult literacy rate in 2005. Turkey, Peru, Mexico, and Brazil had the minimum values among the countries analyzed, with an average adult literacy rate of 90%.

The other socio-economic indicator was income *per capita* in each country. When considering countries' economic power, Peru, Thailand, Bulgaria and Kazakhstan rated low on this indicator, meaning that these countries were placed low when it came to national income. Some OECD countries placed between the higher-income countries, the latter including Denmark, Iceland, Finland, and the United States. The average income *per capita* (as of GDP) was 45000 which it also refers to higher-income countries within the countries which are included to the analysis.

Research question 2: Multiple regression analysis was conducted to answer the second research question, and variables observed across time were organized as a time series.

To investigate the relationship between structural quality indicators which are for the years 1990-2005 and PISA success for the years 2000-2005, retrospective data were used, and these were related to the period almost 10 years before PISA to represent conditions of participant students' pre-primary years.

Table 2. ANOVA Table for Whole Model (from 2000 to 2015 PISA years)

Model	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig**
Regression	314710.92	8	39338.86	45.621	.000
Residual	165562.86	192	862.31		
Total	480273.78	200			

Note. R= .809, R^2= .655, F (8, 192) = 45.62, p<.005

The results of multiple regression analysis showed that the test was significant for this model, F (8, 192) = 45.62, p < 0.00, R^2 = 0.65, and for regression as a whole, p=0.00 (Table 2). This indicates the overall significance of the test, and shows that the model was correctly specified. The total variance explained by the model was 65%, which is highly respectable.

Table 3. The Results of Regression Analysis for Country Comparison

PISA	**B**	***β***	**T**	***p***
Public Expenditure	62.86	0.26	4.28	0.00*
Private Expenditure	2.01	0.02	0.47	0.64
Adult Literacy Rate	4.49	0.41	7.39	0.00*
Enrollment Rate	0.15	0.07	1.19	0.23
Income per capita	0.00	0.43	8.35	0.00*
Pupil/teacher Ratio	-1.88	-0.26	-4.94	0.00*
Starting Pre-primary Age	2.44	5.65	0.43	0.67
Duration of pre-primary Edu.	-3.74	-0.06	-0.77	0.44

p< .005

The results revealed that some of the variables had statistically significant impacts under the conditions of the countries analyzed (Table 3). According to this model and analysis, the results suggests that a one percentage point increase in the public expenditure (β= 0.26) rate led to an increase of 62.86 points in the PISA score in science literacy for whole countries while other variables remained constant. This was the largest beta coefficient for later academic competency at country-level, meaning that this variable made the strongest unique contribution to explaining the dependent variable, when the variance explained by all other variables in the model was accounted for. As indicators, adult literacy rate (β= 0.41), income *per capita* GDP (β= 0.43), and pupil-teacher ratios (β= -0.26) also had a substantial impact on PISA scores. In contrast, it was found that private expenditure in pre-primary education, enrollment rate, age of beginning pre-primary education, and the duration of pre-primary education were not statistically significant.

Discussion

The Dual Face of Spending on Children

A main focus of the study was to investigate the association between private and public expenditure in pre-primary education and students' competency in science literacy in PISA. Previous studies have revealed that more suitable socioeconomic environment can help children to reach better education standards and better learning environment is important for children's academic achievement and beyond (Blankenau & Youderina, 2015). In that point, physical learning environment, science equipment, materials, and resources are important factors in boosting children's science learning (Buldu, Buldu, & Buldu, 2014), and can help to reveal their potential in this area. For instance, an abundance of science materials can boost children's and teachers' motivation in science teaching (La Paro & Pianta, 2000; Yi, 2006). However, all of these physical environmental factors depend on educational funds in some way. In accordance with the results of these previous studies, the present study revealed that public expenditure in pre-primary education is a statistically significant predictor of a nation's performance in PISA science literacy; private expenditure was not statistically significant in the context of this model.

Parallel with the result of the study, Macours, Schady and Vakıs, (2012) claim that investment in early childhood education is crucial for achieving a good performance in school and in life. Therefore, educational expenditure has achieved prominence, because public spending is a significant determinant of social and educational outcomes (Güngör & Göksu, 2013; Heckman, 2000). Similarly, in order to achieve improvements in the quality of

education and later school success, the United States of America has spent more money on children and families than it has on the elderly, due to cash and cost benefits in recent years, which is in contrast with all OECD countries (Isaacs, 2009). In addition to this, Blankenau and Youderina (2015) claims that one of the main benefit of public spending is that government spending can straighten the link between weakening parental income and education spending for a child. Therefore, they found that public spending is more effective when it is spent to low income families because of more effective return of money. Consistent with these study results, the current study provided an idea of the relation between spending money on pre-primary education and academic performance on PISA. Since the main purpose of public spending is to provide education for all (Batare, 2012), public schools are the predominant institutions in pre-primary education in most European countries, for example, Norway, Sweden, Finland, and France (Robson, 2009).

When considered the hypotheses regarding the effective return of pre-primary education expenditure, the results of the current study also provide important information for countries which are spent less to pre-primary education. For instance, Turkey is one of less spending and under-performed OECD countries in PISA. In Turkey, the level of spending in both the public and private sectors was markedly less than it was in other European Countries (World Bank, 2013). European countries spend around 0.3 to 0.5% of their GDP on early childhood education, whereas this figure is only 0.03% for Turkey (World Bank, 2013). In addition, Turkey spent the least amount of money compared to all of the other countries analyzed in the present study (Table 1). For example, while Finland allocated 0.30% of its budget to public expenditure, Turkey only spent 0.02%.

When considering the expenditure level in pre-primary education and performances in PISA in Turkey and in other countries, Turkey has greatly lagged behind in both. Therefore, less spending countries should review their expenditure level in the light of these results. Kaytaz (2004) stated that considerably more money must be allocated to early childhood education to improve average scores sufficiently to occupy one of the top places in PISA.

As Table 1 shows, most of the countries analyzed prefer to use public resources and provide free early education (e.g., Italy, Spain, Russia, Hungary, Thailand, Denmark, and Finland), and compared to the private expenditure level, their public expenditure level is very high. The underlying reason for governments' efforts could be attempt to provide equality for children whose families do not have sufficient economic means to pay for pre-primary

education. In addition, as is known, the public sector is preferable for low-income families, due to the high cost of private preschool institutions (World Bank, 2013). In view of the information above, the association between effective public expenditure and educational achievement and national benefits are clearly related.

Insight into Class Ratios

Within the aim of the current study, one of the predictors of students' performance in PISA science literacy was pupil–teacher ratios during pre-primary education. The countries sampled in the current study had differing pupil-teacher ratios (Table 1); while they were fairly low in most European countries, some countries, such as Turkey, Korea Israel, Argentina, Peru, Thailand, and Mexico, had considerably high ratios. In addition, as is seen in the table 3, a statistically significant relationship between pupil–teacher ratios in pre-primary education and PISA science literacy scores was observed. A variety of studies conducted to evaluate the effect of pupil–teacher ratios on children's later academic competency in various learning areas revealed similar findings, and concluded that small classes during early grades can, in some circumstances, improve students' overall achievement (Finn & Achilles, 1999; Heckman, 2008; Iacovou, 2001). Blatchford et al. (2011) investigated the effect of smaller classes on quality of learning and teaching, and one of their major findings was that small classes have positive effect on pupil academic achievement and the duration of teaching time in smaller pre-primary education classes is longer than it is in larger classes. In accordance with these results, the finding of the current study suggests that a reduction in pre-primary class size can produce an improvement in results in terms of science competency in later years.

A possible explanation of the relationship between small classes and achievement is that young children require high energy levels and constant attention from their teachers during the early years. When managing small groups and fewer children, teachers can devote more time to each child. Therefore, teachers can have longer conversations with children and more easily observe their interests and development in different content areas. These points may ensure high-quality pre-primary education and a positive on children during later stages of life (Barnett, Schulman, & Shore, 2004).

Expansion in Pre-Primary Education

The present comparative study assessed the effect of enrollment rate on competency in science literacy in the PISA. Although the results did not indicate a statistically significant association between enrollment rate and PISA success, countries with high enrollment rates,

such as Finland, Japan, Korea, and Thailand, tended to show a better PISA performance (Table 1). Contrary to the results of the current study, PISA results showed that countries with a consistently high enrollment rate had high PISA success in each assessment cycle (OECD, 2015). Of course, a high enrollment rate alone may not guarantee that a country has a high PISA success rate, but the underlying reason behind this contradictory result could be the quality of the pre-primary education and the structure of the education system of these high-performing nations (Pascal et al., 2013; Bertram et al., 2016). In that point, to explain the relationship between high enrollment rate and countries' PISA success, process quality indicators in pre-primary education could be investigated addition to the structural quality indicators.

In addition, most of the countries that were analyzed already had almost 100% pre-primary education enrollment rates (e.g., Italy, Spain, France, Australia, Estonia), as shown in Table 1. Therefore, low enrollment rates in pre-primary education is not an issue in these countries. However, Turkey fails in this respect. According to the World Bank data source (2017), Turkey had a 37% gross enrollment rate in pre-primary education in the 2014–2015 school year. Moreover, an unequal enrollment rate in pre-primary education is highly noticeable between different districts in that country. Accordingly, the Fares et al. (2007) indicated that a low family income is a considerably important reason behind a low enrollment rate. A second important reason is a low schooling ratio in some countries, such as Turkey, so it is crucial to identify why this is the case.

Variations in the Wealth of Countries

Income is an important issue in educational settings, because learning opportunities are shaped by children's socioeconomic conditions (Dahl & Lochner, 2012). Previous research has indicated that school conditions contributed to more socioeconomic status and socioeconomic status of parents can encompass the quality of education (Aikens & Barbarin, 2008). In this regard, there are numerous studies that investigated the link between income and academic achievement (Reardon & Chmielewski, 2012). For instance, Oxford and Lee (2011) revealed that low-income parents are less able to provide a stimulating environment to improve their children's cognitive development.

Similarly, the main reason for the selection of income variable in the present study was to attempt to understand whether or not the level of economic development of different countries lies behind a well-established education system. As the term "high-income countries" generally refers to more economically developed nations, GDP and *per capita*

income (gross national product) are viewed as the economic criteria for standards of living conditions. Because the recent trend in the economy has shown that socio-economic well-being is positively associated with income (Sacks, Stevenson & Wolfers, 2012). Therefore, individual countries' income *per capita* was evaluated in the present study, in order to understand its effect on children's performance, and it was found that income variables have a significant impact on countries' performance in the PISA assessment.

Consistent with the result of the study, a variety of studies have shown that there is a close relationship between families' income levels and children's academic achievement (Dahl & Lochner, 2012; Kaushal, Magnuson, & Waldfogel, 2011). For example, Olgan (2008) stated that children's socio-economic status was a significant factor in their science achievement in kindergarten and first grade. However, the income achievement gap is growing daily, meaning that it is greater now than ever before (Reardon, 2011). In addition, another issue related to families' low socio-economic status is the negative impact on a family's stress level in terms of the parents' financial strain. This form of stress can limit the parents' interaction with their child, or children, and has an inverse effect on the children's developmental outcomes (Oxford & Lee, 2011).

Age of Beginning Pre-Primary School and Duration

The results of the present study revealed that the duration of, and age of beginning, pre-primary education variables were not statistically significant contributors to countries' science literacy scores in PISA. As indicated in most previous studies, pre-primary education is a highly important factor in children's cognitive development before entering the world of formal learning (Haque et al., 2013; Jacinta & Rotich, 2015). As a significant amount of children's physical, social, and intellectual development occurs between birth and the age of 6 years, children should learn by engaging with the world and their peers. On the effectiveness of pre-primary education, Berlinski, Galiani, and Manacorda (2008) evaluated the effect of pre-primary attendance on children's subsequent school outcomes and concluded that, as time progressed, there was an increased difference between the students who receive pre-primary education and the students who do not receive pre-primary education. In addition, Berlinski, Galiani and Manacorda (2007) reached the same conclusion, and also stated that the test scores of children who attended 1 year of pre-primary education were 8% higher than those of children who did not attend pre-primary education.

However, age of beginning pre-primary education and duration variables are not associated with children's subsequent science literacy performance in PISA for the current

study. These contradictory findings could be because ineffective pre-primary education systems do not allow these children to gain such skills if they remain in pre-primary education for longer (OECD, 2011). Therefore, it is not possible to assume that all pre-primary education systems provide high-quality educational standards. Although the current study did not specifically assess pre-primary education teachers' teaching competency and confidence, these points should be considered while discussing values related to duration in pre-primary education and age of beginning pre-primary education. It is possible that confident and competent teachers are more devoted to children and children's education, thus children obtain benefits from school time (Olgan, 2015).

Adult Literacy Rate

Parental education level is widely recognized as a substantially important contributor to children's educational outcomes (Davis-Kean, 2005; Dearing, McCartney & Taylor, 2002; Jabor et al., 2011), so adult literacy is one of the variables in the model that helps in predicting performance in PISA science literacy among countries. The country-level data showed that adult literacy rate was a statistically significant variable for performance at an international level. The results of the current study are in accordance with those of Dubow, Boxer, and Huesmann (2009), who investigated the long-term effects of parental education level and occupation in a sample of 8-year-old children and their parents. Using socio-economic status and children's IQ, indices of the children's subsequent success were obtained 40 years later. The results showed strong evidence of parental education level having an effect on children's later competency in different learning areas. The previous studies also support the relationship between the parents' education level and the child's cognitive development (Andrade et al., 2005; Jabor et al., 2011; Reardon, 2011; Reardon & Chmielewski, 2012), where they all concluded that there is a strong link between parental educational status and their children's achievement.

Educational Implication and Suggestions

The current study presents a body of evidence in which structural quality indicators play a crucial role in explaining the effectiveness of pre-primary education in later science literacy scores. The results have some implications for policymakers with regard to creating new agenda for innovations in early childhood education because the latter is beneficial in strengthening countries' economic and social outcomes (Berlinski et al., 2008; Heckman, 2008). The results of the present study provide a body of information regarding the profiles of countries with regard to their early childhood education systems. One of the main findings

revealed that adult literacy, public expenditure, income, and pupil–teacher ratios all made specific contributions to countries' performance in PISA science literacy. In this context, the results can provide valuable information to the countries that performed below the OECD average, including Turkey. The science literacy mean score of Turkey is 425 when compared to an average of 493 points in OECD countries.

The results of the present cross-country analysis clearly show that public expenditure plays an important role in countries' performance in PISA, and Turkey spent the least of all the countries assessed. It is hoped that the results will help to demonstrate the importance of public spending on pre-primary education, and it is suggested that countries that spend less on pre-primary education increase their current public spending and plan a detailed pre-primary expenditure agenda for the public sector.

The other important variable in children's later educational performance is income. With that in mind, the current study focused on income per person which is determined as the indicator of countries' economic conditions and educational performance in PISA. Therefore, it is important to eliminate the undesirable results of income disparity within societies. In order to minimize the effect of such disparity, it is vitally important to help disadvantaged children by expanding early childhood education in the deprived regions of countries. However, as much as educational expenditure is a highly effective way of increasing the success of nations' education systems, private expenditure remains open to debate. The private sector is not dominant in early education in most OECD countries (OECD, 2013), primarily because these countries aim to provide free early education for all children, and therefore transfer their public sector funding to early childhood education (Batare, 2012). In this manner, it may be possible to reach all children in every part of a country, and it could be suggested that a substantial amount of pre-primary education should be provided by the government, as it is in most European countries, such as Finland, Germany, and France (Urban, 2008).

Although country-level analysis did not indicate that enrollment rate in pre-primary education was a statistically significant variable in students' subsequent science literacy performance, the countries that had a high enrollment rate showed an improved performance in PISA compared with Turkey (OECD, 2015). Therefore, the provision of high-quality early childhood education can have an important effect on children's subsequent literacy levels, so it is crucial to raise awareness, for example, by raising parents' awareness of the importance of early education. Moreover, nations' ministries of education could develop a system to keep

track of young children who are not attending early education; such precautions may help to increase the enrollment rates in early childhood education programs. More specifically, Turkey has problems concerning low pre-primary education enrollment rates, due to large discrepancies between various districts of the country (UNESCO, 2015). In 2011, the overall enrollment rate in Turkey was approximately only 29%, compared to over 80% in most countries, for example, Japan, South Korea, and New Zealand (UNESCO, 2008). Therefore, in addition to the aforementioned suggestions, which can help to solve problems in early childhood education in Turkey, more public preschools could be built and the cost of pre-primary education could be met by the government.

Another considerably important issue is that attending early childhood education is particularly crucial for disadvantaged and at-risk children in terms of closing the gap in later academic achievements in science, mathematics, and reading (Kağıtçıbaşı, Sunar, & Bekman, 2001). Although the age of beginning pre-primary education and the duration of pre-primary education variables were not statistically significant, various previous studies have revealed that early intervention is a statistically significant contributor to children's IQ and later success (Kağıtçıbaşı, et al., 2001; Murungi, 2013). Therefore, parents should be informed of the benefit of early childhood education on their children's well-being. In low-performing countries in particular, the more time children spend in early childhood education the more successful they will be in school in the future (Dubow, Boxer, & Huesmann, 2009).

Furthermore, according to our cross-country results, pupil–teacher ratio appears to have great importance with regard to performance in subsequent academic life. Unfortunately, the pupil–teacher ratio in some of the countries assessed is still far above that of the OECD average, as it is in Turkish pre-primary classes, for example. In order to improve the quality of peer-to-peer interaction and in-class activities, the child–teacher ratio should be set at a certain level (Duflo, Dupas, & Kremer, 2011). It is therefore important to decrease the number of children in Turkish preschool classes.

The present study also found that literacy ratio, in other words, parental education level, had an important influence on students' science literacy scores, just as previous studies have revealed the importance of parental education (Bicer, Capraro, & Capraro, 2013; Dubow, Boxer, & Huesmann, 2009). Turkey's adult literacy rate has increased to 95.78% in recent years, as a result of national literacy campaigns. Although this rate dramatically increased over the last year, significant differences between the different districts in Turkey can be observed (TUİK, 2015). According to the *Education at a Glance* report (OECD, 2010),

parents with a low level of education represent 85% of the entire population of Turkey. In order to overcome this problem, it is clear that parents' education level should be raised.

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