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Investigation of Factors Associated with Science Literacy Performance of Students by Hierarchical Linear Modeling: PISA 2015 Comparison of Turkey and Singapore *

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Abstract

This study aimed to investigate the extent to which variables directly related to science, which are found in the Programme for International Student Assessment (PISA) 2015 survey predicted the science literacy performance of students in Turkey and Singapore samples and determine the differences and similarities between the samples of the two countries. The study used the relational screening model. The study sample consisted of a total of 9680 students at the age of 15, which included 4643 students from the Turkey sample and 5037 students from the Singapore sample. Also, the sample included 177 schools from Turkey and 163 schools from Singapore. The study used the Hierarchical Linear Modeling (HLM) statistical technique, which is appropriate for hierarchical data because the school and student-level variables were together in the study. According to the findings of the study, science literacy performance indicated a significant difference between schools for both countries. However, approximately 52% of the difference in students' science literacy scores for Turkey sample and 34% for Singapore sample were found to stem from differences between schools. Student-level interest in science, research-based science teaching and learning practices, teacher support in science lessons, science self-efficacy, teacher-centered science teaching variables, and the proportion of science teachers at school level were determined to be a significant predictor of science literacy in both countries. However, the variables which are the significant predictors of science literacy were found to be "the enjoyment of science" for Turkey and "the disciplinary climate in science courses" variable for Singapore. On the other hand, the proportion of science teachers with an undergraduate education of four years or more, which is one of the school-level variables, was found to be not a significant predictor of science literacy performance fro both countries.

Keywords

Science Literacy
PISA
Singapore
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Introduction

To lift their level of development to a higher level, countries need individuals who can adapt to new developments in line with the expectations of the age, do research, or question, who have high self-confidence, and shortly, who are self-realized. These needs of countries can only be met by education. This relationship between education and the level of development has increased the need for much more valid and reliable measurement outcomes in terms of countries' accountability in education. Accountability in education is addressed in three dimensions. These are compliance with guides and regulations, compliance with professional norms, and accountability that is based on outcomes. In other words, accountability that is based on student learning is considered to be much more important (Anderson, 2005). Therefore, the results of large-scale educational studies conducted internationally in accordance with the need for standard measurement and evaluation systems related to student learning are of great significance (Anderson, Lin, Treagust, Ross, & Yore, 2007).

One of these is the Programme for International Student Assessment (PISA), which is organized by the Organization for Economic Co-Operation and Development (OECD) that is known as the biggest of the international educational research. With PISA, the aim is to measure students' status of having characteristics such as analytical, reasoning, and effective communication skills and to obtain indicators for policy-making according to these regularly obtained results. PISA also gives important feedback to countries relating not only to student learning but also many factors, such as student, teacher, parent, and school characteristics, which may affect it. Thus, countries have the opportunity to have a picture of their education systems based on the results of the application. Accordingly, countries can make in-place and important evaluations about their education systems and thus they can direct their education reforms as well. The data collected from PISA assessment produce very important outputs at national and international level (Ercikan, Roth, & Asil, 2015; McGraw, 2008; Niemann, Martens, & Teltemann, 2017; Sjøberg, 2015). In recent years, significant criticisms also take place in the literature about PISA. Accordingly the critics such as inability to develop fair and objective tests in which the cultures of countries are considered, lack of the relationship between educational resources such as budget and physical infrastructure of countries with scores from tests that validity and reliability problems of the data obtained also limits comments on the assessment. (Butler & Adams, 2007; Demirtaşlı & Ulutaş, 2015; Dancis, 2014; Feniger & Lefstein, 2014; Hopfenbeck et al., 2017; Leung, 2014; Pons, 2017; Sjøberg, 2015). The presence of positive and negative interpretations of PISA application increases the importance of studies on the data of the application.

The international student assessment program, PISA, is conducted with a repeated cycle of once every three years. In each PISA cycle, one of the main areas of mathematics and science literacy and reading skills is determined as the weighted field. With PISA, the concept of literacy has become a primary topic on the agenda for both participating and non-participating countries. Literacy is defined as reaching, using, accepting and evaluating written sources to develop the knowledge and skills necessary for individuals to play a more effective role in society and to contribute to society (OECD, 2006). According to UNESCO - United Nations Educational, Scientific and Cultural Organization (2016) literacy is the ability to define, comprehend, interpret, assemble, account and communicate with various types of written sources. Science literacy is a competence that combines cognitive, affective and psychomotor skills about science.

In PISA 2015, science literacy is defined as "the ability to deal with ideas and problems related to science as an efficient citizen" (Ministry of National Education [MoNE], 2016). An individual who is a science-literate is willing to participate in conversations on certain logic about science and technology. This requires the ability to make scientific explanations, design a scientific research method, and do scientific interpretation and evaluation of the data obtained and findings obtained from the data (MoNE, 2016). Science literacy is a competence that combines cognitive, affective and psychomotor skills about science (Durant, 1993). There are also affective factors affecting the students' science literacy competencies. This is evident when the four dimensions of the assessment framework for the science literacy given below are examined.

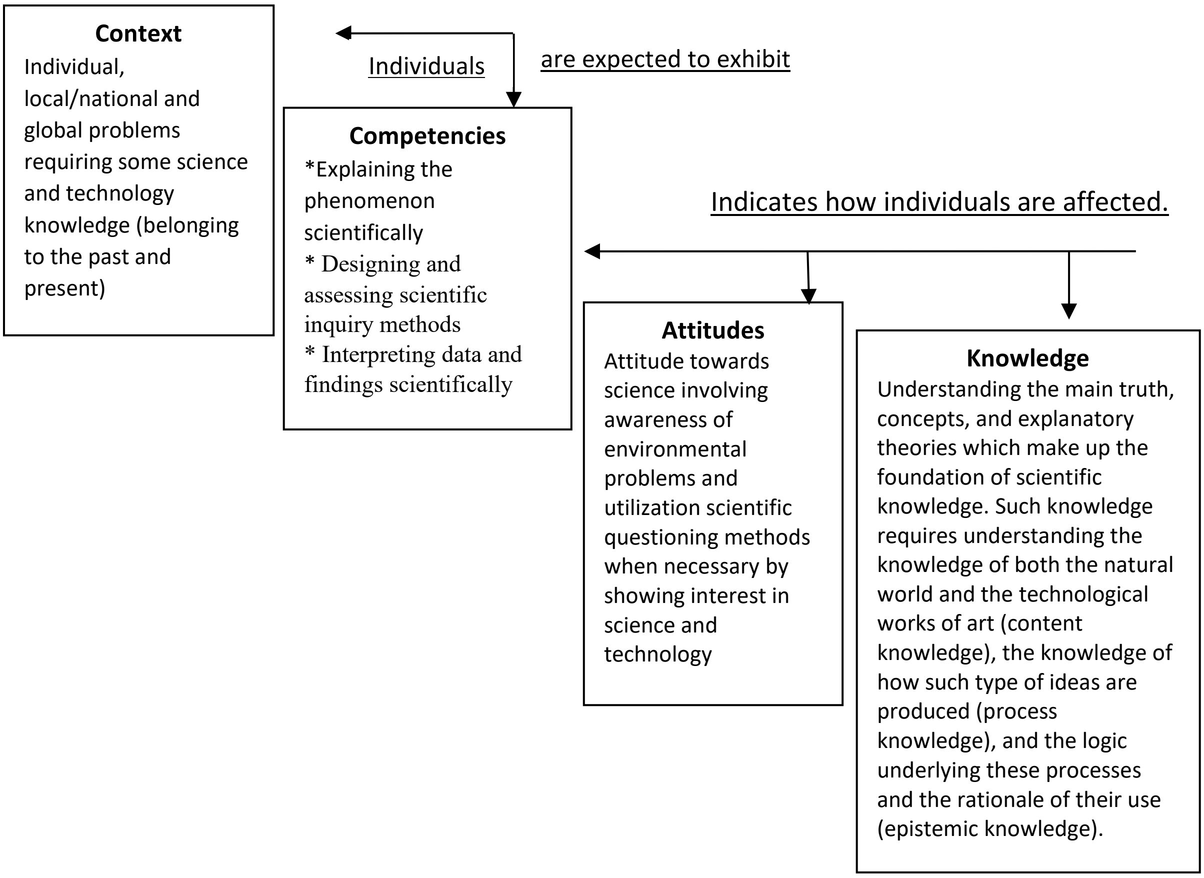

Figure 1. Evaluation Dimensions of Science Literacy (OECD, 2016)

The examination of the dimensions of science literacy assessment in Figure 1 shows that attitudes are considered as an important dimension related to science literacy. Students' tendencies and attitudes towards science can affect their level of interest and maintain their participation in the lesson by motivating them to mobilize (Osborne, Simon, & Collins, 2003). Many studies show students' beliefs in themselves and affective characteristics are effective on their learning levels (Jinks & Morgan, 1999; Onwumere, 2003; Paolucci, 2001). Academic self-perception, known to be closely related to student achievement, is considered as an important outcome of education (Marsh, 1986, as cited in OECD, 2007). With PISA application, important measurements are performed regarding the affective characteristics of students. However, the variables related to the weighted area are also evaluated in each cycle. The PISA 2015 application also did some assessments for variables directly related to science, such as science self-efficacy, interest in science, and teacher-centered science teaching, which are considered effective for science literacy by the OECD. In PISA, science literacy is measured not only at the student level but also at the school level. It is important to determine whether the science-related student and school-level variables (science self-efficacy, enjoyment of learning science, etc.) directly involved in the application and considered effective by the OECD are a significant predictor of science literacy performances of students as predicted.

The examination of studies investigating variables about science literacy indicates that the variable that is mostly associated with students' success in science literacy is the level of parents' education (Anıl, 2009; Boztunç, 2010; Karabay, 2012; Şaşmazel, 2006; Yıldırım, 2012). There is a positive relationship between success in science literacy and socio-economic level, the number of books in the house, the geographical environment in which the child lives and the study environment in the house (having a room, a desk, and a quiet environment to study), computers and Internet facilities at home, and time allocated for learning (Albayrak, 2009; Anıl, 2008, 2009; Anıl & Özer, 2012; Boztunç, 2010;

Demir, 2016; Erbaş, 2005; Gümüş & Atalmış, 2012; Güzel, 2006; Karabay, 2012; OECD, 2004; Özer, 2009; Özer & Anıl, 2011; Perry & McConney, 2010; Sarıer, 2010; Spiezia, 2010; Şaşmazel, 2006). Kaya and Doğan (2017) found a statistically significant relationship between students' science literacy and the number of books, computers and cell phones in their homes, and that there was a significant difference between the students' science literacy and the presence of the classics and poetry books in four countries (Turkey, Finland, the US, and Israel). One of the variables determined to negatively affect science literacy is the use of computer and the Internet as an entertainment tool (Demir, Kılıç, & Ünal, 2010; Duman, 2008; Gürsakal, 2012; OECD, 2004). According to Beaton et al. (1996), there is a positive relationship between science literacy and weekly time allocated for extracurricular work. On the other hand, another study has found that there is no relationship between science literacy and the time spent for the weekly extracurricular study, but that it positively increases attitudes towards school (Erbaş, 2005). In addition to socioeconomic level, which is among the important variables that affect PISA success, gross national product per capita (GNP) or financial spending is also one of the variables that take attention. Accordingly, the PISA success increases as GNP per capita increases in countries with GNP per capita below $50. However, the same effect is not observed in countries with GNP per capita above 50 dollars. The finding that per capita expenditures does not guarantee success in PISA has been supported by other studies, as well (Agasisti, 2014; Cheung & Chan, 2008; OECD, 2012).

Science educators always emphasize the importance of taking both cognitive and motivational aspects of science literacy into account (Millar, 2006). One of the most important features affecting the learning process of students is their belief that they can learn. The belief that a person can perform a task is called self-sufficiency (Bandura, 1982). Bandura and Locke (2003) argued that none of the tools available in educational studies have the same capacity as self-efficacy in predicting student achievement. Many studies suggest that there is a positive relationship between self-efficacy and student achievement in PISA assessment, that is, as students see themselves sufficient in science, their performance in science literacy increases (Anderman & Young, 1994; Britner & Pajares, 2006; Çalışkan, 2008; Lau & Roeser, 2002; Pajares, 1996; Palmer, 2006; Usta, 2009). In a study on PISA 2015 Turkey sample, self-sufficiency in science and intrinsic and instrumental motivation for science have been determined to be important predictors of science literacy (Kartal, Kula, and Kutlu, 2017).

Scientific research has become the focus of studies in science education in the last century (Lederman, Lederman, & Antink, 2013; Nehring, Nowak, Zu Belzen, & Tiemann, 2015). Scientific research is not only the heart of science and science learning (National Research Council [NRC], 1996) but also an essential component of science literacy (Bybee, 2002; Nowak, Nehring, Tiemann, & Upmeier zu Belzen, 2013). Some studies have found that research-based learning and teaching activities can improve students' learning performance (Anagün, 2011; Blanchard et al., 2010; Chiang, Yang, & Hwang, 2014; Furtak, Seidel, Iverson, & Briggs, 2012; Lee, Deaktor, Hart, Cuevas, & Enders, 2005; Lynch, Kuipers, Pyke, & Szesze, 2005; Minner, Levy, & Century, 2010; Tal, Krajcik, & Blumenfeld, 2006; Wolf & Fraser, 2008). However, the increase in the level of satisfaction in the field of science by which students associate themselves increases the importance they attach to scientific research. The importance attached to scientific research and science literacy performance shows a positive correlation. Science education by which students experience research-based teaching and learning has a more positive effect on science as well as the possibility of having stronger science literacy (Woods-Mcconney, Oliver, Schibeci, Mcconney, & Maor, 2013).

Another variable that is known to have significant effects on science literacy is teacher support in the science class. Teachers are accepted as one of the most powerful and fundamental factors responsible for the success of students (Akiba, LeTendre, & Scribner, 2007; Darling-Hammond, 2004; Greenberg, Rhodes, Ye, & Stancavage, 2004; Greenwald, Hedges, & Lain, 1996; Hedges, Lain, & Greenwald, 1994). Teachers can shape students' progress in the classroom with their instruction and interaction with students (Dietrich, Dicke, Kracke, & Noack, 2015). The supportive teacher-student relationship is positively related with particularly the amount of the teacher support perceived by students, students' motivation, involvement, and interest, development of students' internal values and efforts, and academic achievement (Cornelius-White, 2007; Den Brok, Levy, Brekelmans, & Wubbels, 2005; Dietrich et al., 2015; Furrer & Skinner, 2003; Murray, 2009; Roorda, Koomen, Spilt, & Oort, 2011; Wentzel, Battle, Russell, & Looney, 2010).

Studies provide evidence that positive disciplinary environment in the classroom with supportive teacher-student relationship supports student achievement and motivation (Arum & Velez, 2012; Cheema & Kitsantas, 2016; Elliott & Phuong-Mai, 2008; Fan, 2012; Figlio, 2007; Frempong, Ma, & Mensah, 2012; Gamoran & Nystrand, 1992; Hamre & Pianta, 2001; Hughes, Wu, Kwok, Villarreal, & Johnson, 2012; Jenkins & Ueno, 2017; Lassen, Steele, & Sailor, 2006; Ma & Williams, 2004; Marks, 2010; Marzano & Marzano, 2003; McCormick, O'Connor, Cappella, & McClowry, 2013; Mikk, Krips, Säälik, & Kalk, 2016; Ning, Van Damme, Van Den Noortgate, Vanlaar, & Gielen, 2015; Roorda et al., 2011; Sanders & Jordan, 2000). Disciplinary climate refers to students' perceptions of the stability and effectiveness of classroom rules and the frequency of disciplinary events among students in the classroom (eg, disrupting the class order) (Cheema & Kitsantas, 2016; Dempsey, 2008). PISA 2015 also includes items on the disciplinary climate 'to learn about the structure and effectiveness of classroom management, which is seen as a prerequisite for student learning'. Students are asked to explain how often events taking place in the classroom and disrupting classroom order take place (i.e., students do not listen to the teacher) (Klieme & Kuger, 2014). Studies on the relationship between classroom climate and science literacy suggest that science literacy increases as the discipline increases in the classroom (Akyüz & Pala, 2010; Güzel, 2006; OECD, 2004). According to the regression analysis conducted on PISA 2015 Beijing, Shanghai, Jiangsu, and Guangdong China samples, it was found that instead of teacher support, the disciplinary environment was more effective in the relationship between research-based science activities and science literacy for both gender groups (Chi, Liu, Wang, & Won Han, 2018).

The variable of "enjoyment of learning science" is means that students have fun and feel happy while they are participating in science learning activities (Shumow, Schmidt, & Zaleski, 2013). The enjoyment of learning science is based on positive relationships with peers, teachers (Jen, Lee, Chien, Hsu, & Chien, 2013), and science teaching strategies (e.g. applied activities) (Hampden-Thompson, & Bennett, 2013; Shumow et al., 2013). Laukenmann et al. (2003) state that the enjoyment of learning science plays an important role in student achievement and it is the main driving force for self-learning. Non-enjoyment of learning science is seen as one of the main reasons for people who cannot reach their potential (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). Positive emotions and the enjoyment of learning science have an important place in learning performance (Koller, Baumert, & Schnabel, 2001). In studies for many countries on the enjoyment of learning science and success such as United States (Grabau & Ma, 2017), Canada (Areepattamannil & Kaur, 2013), Finland (Lavonen & Laaksonen, 2009), Hong Kong (Lam & Lau, 2014), Malaysia and Singapore (Ng, Lay, Areepattamannil, Treagust, & Chandrasegaran, 2012), Saudi Arabia (Tighezza, 2014), Taiwan (Jen et al., 2013; Tsai & Yang, 2015), a positive relationship was found between the enjoyment of learning science and science achievement. On the other hand, the relationship between science literacy and the enjoyment of learning science was determined to be negative in the Middle Eastern and North African countries (Bouhlila, 2011).

The concept of 'interest' as a criterion to determine the degree to which young people acquire the knowledge and skills related to science literacy that they may need in their adult life has been discussed in the scope of the PISA science framework (OECD, 2006). Interest in science is defined as the tendency to engage in science activities in and out of school. Interest in decisions related to the lesson, work, and career choice is considered as one of the strongest predictors (Olsen, Prenzel, & Martin, 2011).

Interest plays an important role in initiating, directing and supporting interaction in learning processes and specific areas (Renninger, Hidi, & Krapp, 1992; Schiefele, 2009). Interests are specific to the area (Häussler & Hoffmann, 1998; Krapp & Prenzel, 2011). The relationship between interest in science and success (at the country level as well as at the individual level) has been the subject of studies for more than 40 years (Baumert & Köller, 1998; Osborne, Simon, & Collins, 2003). Albayrak (2009) in his study on PISA 2006 concluded that there was a negative relationship between interest in science and science literacy performance.

Teacher-centered teaching is defined as approaches in which the teacher controls the course content and course to a great extent (Ormrod, 2012). It is a process where classroom discussions are presided by the teacher and the knowledge required for student learning is transferred by the teacher. Although there is a common perception that such practices are being used less frequently (Swaak, De Jong, & Van Jooligen, 2004), they are still used more often and more dominantly than student-centered approaches in many countries (Echazarra, Salinas, Méndez, Denis, & Rech, 2016). Unlike research-based teaching practices, the student in teacher-centered teaching is passive. Teacher-centered teaching seems to be advantageous in terms of easier classroom management, access to a larger part of the content, and better preparation for standardized tests (Ormrod, 2012). A positive and significant relationship between students' opinions on teacher-centered teaching practices and their science performance has been determined only in Indonesia, while the relationship has been negative in Korea (OECD, 2018). In some studies examining the relationship between teacher-centered teaching and science performance, a positive relationship has been found between the two variables (Yayan & Berberoğlu, 2004), whereas the success of student-centered science teaching in the science field has been more effective compared to teacher-centered teaching in others (Schroeder, Scott, Tolson, Huang, & Lee, 2007; Wise, 1996). However, a negative relationship has been put forward between student-centered teaching and science achievement (Aypay, Erdoğan, & Sözer, 2007; Kalender & Berberoğlu, 2008).

In PISA 2015, there are variables related to science literacy at the student level as well as science-related variables at the school level. In a study on PISA 2015 Turkey data, Özkan (2015) determined the following variables as significant predictors: school size, class size, extra-curricular activities provided to students at school, quality of educational resources, student/teacher proportion, school climate affected by factors related to teachers, and quality of physical resources. Özberk, Atalay Kabasakal, and Boztunç Öztürk (2017) examined the mathematical literacy performance of Turkey in PISA 2003 and 2012 applications and reported that the proportion of mathematics teachers, one of the school level variables, was a strong predictor of the average mathematics achievement of a school. According to a study conducted by Acar and Öğretmen (2012) on PISA 2006 application, the science-literacy level of students was found to vary by the location of their school. However, the science-literacy performance was observed to increase as the quality of educational resources in the school and the number of computers with internet connection increased. According to PISA 2000 data, the mediating role of the material, social, and cultural resources of the school in the relationship between scores relating to socio-economic level and math, and science literacy and reading skills were studied in a sample of 30 countries. According to the results of the study, while material resources and cultural factors had a significant impact for many countries, social resources were determined to have a low impact. Also, the study concluded that educational resources had a mediating role in the relationship between student achievement and socio-economic level (Marks, Creswell, & Ainley, 2006). Among studies examining the relationship between school variables and PISA student achievement, no studies have been found on the proportion of science teachers in the school or the proportion of science teachers with 4 or more years of education to the total science teachers.

When studies conducted on science literacy are examined, no studies have been encountered investigating variables in combination, such as science self-efficacy at student level directly related to science, interest in science, discipline conditions in science classes, research-based science education applications, teacher support in science classes, teacher-centered science teaching, the proportion of science teachers at the school level, and the proportion of science teachers with 4 or more years of education to total science teachers. In studies investigating the relationship of science-related variables with science literacy, the variables have generally been handled alone or studied with other variables that are not science-related. These variables, which are considered important by the OECD and are included in the application, differ in terms of the countries participating in the application about whether they predict science literacy. Accordingly, these countries are compared with each other. Such comparisons appear to be important in terms of successful countries in showing how things have changed in relation to other countries and guiding educational reforms. In other words, with PISA application, countries can learn about the results of their own educational status as well as the educational facts in successful countries, which can help realize reforms through benchmarking. Accordingly, the examination of the results of the PISA 2015 application presenting important feedback about science literacy of students indicated that Turkey ranked the 54th among 72 countries and that the average success rate of Turkey with a score of 425 was below the average, compared to the average of all countries (465) and the average of OECD (493). In addition, the mean science literacy score of Singapore, which attracted attention by taking the first place in three areas, was determined as 556 (OECD, 2016). Table 1 presents average scores for OECD and all countries including Turkey and Singapore participating in PISA applications conducted between 2006 and 2015.

Table 1. Some Findings related to Science Literacy Performances obtained from PISA 2006-2015 Applications

	2015	**2012**	**2009**	**2006**
OECD Average	493	501	495	498
Average of all countries	465	477	471	478
Turkey average (Ranking)	425(54)	463(43)	454(42)	424(47)
SingaporeAverage (Ranking)	556(1)	551(3)	542(11)	-
Total number of participating countries	72	65	65	57

As is seen in Table 1, Turkey could not get an average score equal to or above the OECD average in any of the PISA applications. Although the average score of Turkey showed a gradual increase until 2012 application in terms of performance in scientific literacy, a critical decrease was observed in the 2015 application. On the other hand, since Singapore's first participation in the application in 2009, it is noteworthy that the average score of the country in science literacy has been higher compared to that of the OECD and all countries and that it has constantly increased. Taking the case of Turkey and Singapore, the most successful country of 2015 application, together, and doing a comparative analysis is important in terms of determining the deficiencies in the Turkish educational system and the reforms. Andreas Schleicher, director of education and skills at OECD, points out that "Singapore did not only get good results but also did much better".

When the affective characteristics were analyzed in terms of scientific literacy in Turkey sample, the interest and motivation levels of the students in Turkey were found to be much higher compared to the OECD average. Also, the status of the students in Turkey in terms of the enjoyment of learning science and seeing themselves as adequate in the science field was higher than the OECD average. Contrary to the results obtained for affective characteristics related to science for Turkey, the level of science literacy, as aforementioned, was quite low compared to the OECD average. When the results related to the Singapore sample were examined, the interest and motivation levels, which are among affective characteristics, were well above the OECD average, as was the case for Turkey. However, the levels of science literacy, on the contrary to the case of Turkey, were above the OECD average (OECD, 2016).

Singapore and Turkey samples show differences in terms of PISA achievement and other factors affecting achievement. However, there are also similarities and differences in the education systems of the two countries. Accordingly, the education systems of the two countries were briefly discussed. The most important feature of the Singapore educational system is that it has a holistic and broad-based educational understanding. In Singapore, four official languages, namely Chinese, Malay, Tamil, and English, are spoken based on the ethnic distribution of the population (OECD, 2012). In addition to multicultural education, bilingual education is carried out in all levels of education through mother tongue and English medium, including pre-school education. Thus, English is learned by all students. The aim is to achieve the holistic development of students in terms of the following eight basic skills and values: character development, personal management skills, social and collaborative skills, literacy and mathematics skills, communication skills, skills to access information, creativity and reasoning skills, and skills to apply knowledge (Özkan, 2006). In the Singapore education system, primary education is a 6-year process including 1-4th grades as elementary school and 5-6th grades as guidance. Science classes start in the 3rd grade in elementary school. English, mathematics, and mother tongue education starts in the first year of elementary school. In the 5 and 6th grades, there are courses such as English, mother tongue, science, mathematics, social sciences, music, art, physical education, citizenship, and morals education. At the end of primary school, students are given the Primary School Leaving Examination-PSLE, which contains items on English, mother tongue, science, and mathematics. The programs in which students are placed according to the PSLE scores are as follows: Normal Technical, Normal Academic, Specific or Express programs. At the end of four years of secondary education, students who cannot succeed in the "Normal-N" level of the placement exam which is called "General Certificate of Education-GCE" receive technical and vocational training at the ITE-Institute of Technical Education. Students who are successful in GCE-N continue their education for another year At the end of this training, they can take the exams at GCE Ordinary-O level and go to programs called "Technical Education Institute", "Polytechnic", or "Colleges/Centralized Institutes". Students who complete pre-university education can register to universities according to their qualifications approved by School Graduation Certificate and GCE Advanced-A. There are 3 universities in Singapore: “The National University of Singapore”, “Nanyang Technology University”, and “Singapore Management University”. Singapore Business University is a private university (Kaytan, 2007; Özkan, 2006). The underlying factors for Singapore's success in applications such as PISA, TIMMS, and PIRLS are steady and consistent education policies; stability in equal opportunities in education; value given to science, mathematics, and technical skills; teacher quality; visionary school leaders; and effective use of information and communication technologies in learning environments (Levent & Yazıcı, 2014).

The language of education in the Turkish Education System is Turkish, which is the official language. English is taught as a lesson as part of the curriculum. Some higher education institutions use English as the language of instruction. Preschool education is not compulsory as in Singapore. Other education levels in the system have been arranged as 4 years of elementary school (1, 2, 3, and 4th grades), 4 years of middle school (5, 6, 7, and 8th grades), and 4 years of high school education (9, 10, 11, and 12th grades). With the reform put into effect in 2012, the 12-year continuous education was transformed into 12-year compulsory continuous education. After completing elementary and middle school education, students take a central placement test for transition to high school education. Schools are divided into two categories according to the types of placement. The central exam consists of two parts: verbal skills which include Turkish, religious culture and morals, Atatürk's principles and history of Turkish revolution, and foreign language and numerical skills which consist of questions in the fields of Mathematics and Science. The test is prepared based on the learning areas of the 8th-grade curriculum (MoNE, 2019). Students are placed in schools that admit students through central placement test scores (Science and Social Sciences High Schools, Secondary Education Institutions Applying Special Programs and Projects, Anatolian Technical Programs of Vocational and Technical Anatolian High Schools). Students are also admitted to high school institutions requiring no test achievement score according to criteria such as residence addresses, school achievement scores, and low unexcused absences. Students in Turkey are also placed in vocational and technical high schools, Anatolian fine arts high schools, sports high schools, and Anatolian Imam Hatip high schools based on their central test and aptitude test scores. Transition to higher education is a one-step process consisting of different sessions according to the changes put into effect in 2018. Higher Education Institutions Exam (HEIE) consists of Basic Proficiency Test (BPT) and optional Field Proficiency Test (FPT), and Foreign Language Test (FLT). Accordingly, BPT's contribution to placement in higher education is 40%, while the contribution of FPT and FLT has been determined as 60%. There are a total of 206 private and state universities in Turkey (ÖSYM, 2018; YÖK, 2018). The most notable differences between Turkish and Singapore education systems are the existence of bilingual education in Singapore (mother tongue and English), implementation of the local placement in transition to high school education in Turkey, the abundance of high school types in Turkey compared to Singapore, and the impact of proficiency approved by school graduation certificate of students who complete their middle school education.

There are some similarities and differences between Turkey and Singapore in terms of education systems and PISA results. Accordingly, comparative studies of education systems in Turkey and Singapore, which is the most successful country in all three areas of the PISA 2015 application, seem to be important in terms of determining the deficiencies in the Turkish education system and guiding the reforms. The main area in PISA 2015 application was determined as science literacy. However, variables related to science literacy were also evaluated. As mentioned earlier, these variables are considered effective by the OECD for science literacy. They are related to science, they predict science literacy well, and they correlate with each other; for this reason, they were identified as the focal point of this study. The review of the literature indicated that there were no studies handling variables that are directly related to science and affect science literacy. Also, there were no comparative studies handling these variables especially over Singapore and Turkey samples, either. Therefore, this study aimed to investigate the level to which variables directly related to science found in the PISA 2015 application predicted the science literacy of students over the samples of Turkey and Singapore and to reveal the similarities and differences in terms of the two countries. Under this general purpose, the sub-objectives of the study were as follows: in PISA 2015 Singapore and Turkey samples;

(i) Are there any significant differences between schools in terms of the science literacy scores of students?

(ii) What are the student-level variables that show a significant relationship with students' science literacy scores?

(iii) What are the school-level variables that show a significant relationship with students' science literacy scores?

(iv) What are the school-level variables associated with students' science literacy scores when the student-level variables that show a significant relationship with the students' science literacy scores are added to the model?

Method

Research Model

This study aimed to determine the variables which predict the PISA 2015 science literacy performance, primarily at the student level and secondarily at the school level. For this reason, the relational screening model was used in this study because the study aimed to reveal the relationships between the variables the way they existed (Fraenkel, Wallen, & Hyun, 2012; Karasar, 2005).

The Study Group

Approximately 540,000 students representing nearly 29 million 15-year-olds from 72 countries, including 35 OECD members, participated in the sixth cycle of PISA application. The samples from the countries were selected using the two-stage stratified sampling method. During the selection process, first of all, target schools were selected among schools with 15-year-old student groups. Then 35 students from each of the selected schools were selected by simple random sampling. At least 150 schools and 4500 students were selected from each country (OECD, 2016). The study group of this study consisted of Turkey and Singapore samples participating in PISA 2015. The target population for Turkey and Singapore consisted of students aged 15 who participated in PISA 2015 application. Table 2 presents the universe distributions of 15-year-old student groups for Singapore and Turkey.

Table 2. The Universe of 15-Year-Old Student Groups for PISA 2015 Application from Singapore and Turkey

Countries	total universe of the 15-year old group	7th grade or above 15-year-old registered student universe	The number of excluded individuals	Valid target universe
Turkey	1324089	1100074	174.708	925366
Singapore	48218	47050	826	46224

(OECD, 2016)

As is seen in Table 2, 7th grade or above 15-year-old formal education student universe corresponded to 1.100.074 students in Turkey and 47.050 students in Singapore. But for some reason, as indicated earlier, the universe of the PISA 2015 application was 925.366 and 46.224 students for Turkey and Singapore due to excluded students, respectively. Table 3 presents the number of 15-year-old students and schools participating in the PISA 2015 application for Turkey and Singapore. As seen in Table 2, there were 177 schools and 4643 students from Turkey and 163 schools and 5037 students from Singapore.

Table 3. The Distribution of The Number of Students and Schools by Countries

Country	The number of schools	The number of students
Turkey	177	4643
Singapore	163	5037
Total	340	9680

For the comparisons to be more significant, Table 4 presents information about some variables relating to Turkey and Singapore such as national income per capita, the proportion of public education expenditure to GNP (%), the proportion of the salary of experienced teachers to per capita GNP, expenditures per student, the number of students per teacher, the number of science teachers at schools, the total number of teachers at schools, the number of students at schools, and the duration of pre-school education.

Tablo 4. Some Variables for Singapore and Turkey

	Singapur	Turkey
Population	5.604.000	78.666.000
Per capita income	53.053 $	9.316$
The ratio of public education expenditures to gross national product (%)	2,9	2,9
Rate of Experienced Teacher Salary to GNP per Person	82.515	19.788
Expenditure per student	5010 $	1440 $
Number of students per teacher	12	15
Number of science teachers at schools	20	7
Total number of teachers at schools	103	55
Number of students at schools	1232	822
Duration of pre-school education	3.61 year	1.03 year

(OECD, 2015; International Monetary Fund [IMF], 2016; United Nations, Department of Economic and Social Affairs, Population Division [UN], 2015; United Nations Development Programme [UNDP], 2015; UNESCO, 2016)

As seen in Table 4, the population of Turkey (78.666.000) is nearly as much as 14 times the population of Singapore (5,604,000). The share allocated to education expenditures from the gross national product is the same for both countries. However, due to the lower level of national income and the higher number of students in Turkey, the expenditure per student is relatively lower compared to Singapore. While the spending per student in Turkey is $1440, it is $5010 in Singapore. The average number of students in schools in Singapore (1232 students) is greater than in Turkey (822 students). In parallel to this, the average number of teachers in schools is higher in Singapore (103 teachers) compared to Turkey (55 teachers). The number of students per teacher is 15 in Turkey, while it is 12 in Singapore. In terms of the number of science teachers in schools, there is a significant difference between the two countries. While the average number of science teachers in schools in Singapore is 20, it is only 7 in Turkey.

Data Collection

In the study, the data relating to the PISA-2015 Turkey and Singapore samples were collected from OECD official website (www.pisa.oecd.org). The detailed scoring and coding process in the PISA application is carried out by the relevant sides. Application data are arranged by quality control studies before publication. Well-defined processes and procedures are carried out to ensure reliable assessments of student responses (OECD, 2014). The school-level variables included in the study were SC018- The total number of science teachers/The total number of teachers ratio and SC019-The total number of science teachers with 4 years of education or more /Total number of science teachers ratio. The values for these variables are in percentages. The item code, items, answers, and scoring for student-level variables included in the study are given in Table 5.

Table 5. Information about the item code, observed variables, responses, and ratings of the variables in the PISA

Latent Variables	Item code	Observed Variable	Answers and Rating
Enjoyment of science	ST094Q01	I generally have fun when I am learning <broad science> topics.	" strongly disagree =1" " disagree =2" "agree =3" "strongly agree =4
	ST094Q02	like reading about <broad science>.	
	ST094Q03	I am happy working on <broad science> topics.	
	ST094Q04	I enjoy acquiring new knowledge in <broad science>.	
	ST094Q05	I am interested in learning about <broad science>.	
Interest in broad science topics	ST095Q04	Biosphere (e.g. ecosystem services, sustainability)	"not interested=1", "hardly interested=2", "interested=3", "highly interested=4", and "I don't know what this is=0
	ST095Q07	Motion and forces (e.g. velocity, friction, magnetic, and gravitational forces)	
	ST095Q08	Energy and its transformation (e.g. conservation, chemical reactions)	
	ST095Q013	The Universe and its history	
	ST095Q015	How sience can help us prevent diseases	
Disciplinary climate in science classes	ST097Q01	Students don't listen to what the teacher says.	"every lesson=4", "most lessons=3", "some lessons=2" and "never or hardly ever=1"
	ST097Q02	There is noise and disorder.	
	ST097Q03	The teacher has to wait for a long time for students to setle down.	
	ST097Q04	Students cannot work well.	
	ST097Q05	Students don't start working for a while after the lesson begins.	

Table 5. Continued

Latent Variables	Item code	Observed Variable	Answers and Rating
Inquiry-based science teaching and learning practices	ST098Q01	Students are given opportunities to explain their ideas.	"every lesson=4", "most lessons=3", "some lessons=2" and "never or hardly ever=1"
	ST098Q02	Students spend time in the laboratory doing practical experiments.	
	ST098Q03	Students are required to argue about science questions.	
	ST098Q05	Students are asked to draw conclusions from an experiment they have conducted.	
	ST098Q06	The teacher explains how a <school science> idea can be applied to a number of different phenomena (e.g. the movement of objects, substances with similar properties).	
	ST098Q07	Students are allowed to design their own experiments.	
	ST098Q08	There is a class debate about investigations.	
	ST098Q09	The teacher clearly explains the relevance of <broad science> concepts to our lives.	
Teacher support in a science classes	ST100Q01	The teacher shows an interest in every student's learning.	"every lesson=4", "most lessons=3", "some lessons=2" and "never or hardly ever=1"
	ST100Q02	The teacher gives extra help when students need it.	
	ST100Q03	The teacher helps students with their learning.	
	ST100Q04	The teacher continues teaching until the students understand.	
	ST100Q05	The teacher gives students an opportunity to express opinions.	
Teacher-directed science instruction	ST103Q01	The teacher explains scientific ideas.	"every lesson=4", "most lessons=3", "some lessons=2" and "never or hardly ever=1"
	ST103Q03	A whole class discussion takes place with the teacher.	
	ST103Q08	The teacher discusses our questions.	
	ST103Q11	The teacher demonstrates an idea.	
Science self-efficacy	ST129Q01	Recognise the science question that underlies a newspaper report on a health issue.	I can't do this = 1 I would try to do it on my own = 2 I can do it with a little effort = 3 I can do it easily = 4
	ST129Q02	Explain why earthquakes occur more frequently in some areas than in others.	
	ST129Q03	Describe the role of antibiotics in the treatment of disease.	
	ST129Q04	Identify the science question associated with the disposal of garbage.	
	ST129Q05	Predict how changes to an environment will affect the survival of certain species.	
	ST129Q06	Interpret the scientific information provided on the labelling of food items.	
	ST129Q07	Discuss how new evidence can lead you to change your understanding about the possibility of life on Mars.	
	ST129Q08	Identify the better of two explanations for the formation of acid rain.	

(OECD, 2017)

In addition to the data of the countries on student and school variables, plausible values are also included in the analysis. In PISA, not all students receive the same question booklet. Different sets of items are placed in different rows in the booklets. Therefore, plausible values obtained from the probability distribution function are calculated for all students, instead of a single score for the related field. In PISA 2015 application, 10 plausible values were calculated instead of 5 plausible values. In this way, it is possible to create plausible values for questions which are not solved by students who are treated as missing values in PISA data (Rutkowski, Gonzalez, Joncas, & Von Davier, 2010).

Data Analysis

Before starting the analysis of the data, necessary corrections relating to data loss along with outliers examination were made on the data set. Given the aim of the study, the study data was in a hierarchical structure. There were two types of variables in the study: student and school variables. The schools covered the students. However, the characteristics of each school and the characteristics of each student may vary in itself. On the other hand, students are affected by the characteristics of their school. Linear regression analysis was used for data sets of this kind of hierarchical structure. However, in cases where linear regression analysis is used in hierarchical data, the common variance is neglected. Therefore, linear regression analysis is considered inadequate in hierarchical data sets. Hierarchical linear models are a statistical method which is generally based on regression analysis but takes inter-group independence into account by considering the level of each variable. Therefore, hierarchical linear models should be preferred in multilevel nested models because they minimize the probability of incorrect estimations compared to regression analysis (Osborne, 2000; Raudenbush & Byrk, 2002).

In this study, various hierarchical models were used for each objective. Accordingly, for the first sub-objective of the study, a Randomized One-Way ANOVA model was employed to test whether the science literacy scores of the students showed a significant difference by schools. For the second sub-objective, the Level-1 random regression model, which identifies the science literacy performances of students significantly, was used to determine the student-level variables. For the third sub-objective, the Level-2 regression model in which mean values are the output, which predicts the science literacy scores of students significantly, was used to determine the school-level variables. For the fourth and last sub-objective of the study, to answer the question "What are the school level variables associated with the science literacy scores of the students when the student-level variables that significantly predict the science literacy scores of the students are included in the model?", the model in which fixed and curve coefficients are the output was created. Since the first and second level variables take place together in the model, this model is also called the full model (Lee, 2000; Raudenbush & Byrk, 2002). The models established for each sub-objective of the study were repeated for Turkey and Singapore samples. The results of the analysis are given together to make the related comparisons better.

Assumptions of two-level Hierarchical Linear Models were as follows: the normality of errors for Level-1 shows Level-1 errors for each Level-1 unit and normal distribution with a zero mean; Level-1 variables are independent of Level-1 errors; Level-2 errors show multiple normalities with zero means. Level-2 predictors are independent of Level-2 errors. Level-1 and Level-2 errors are independent of each other. Variables of each level do not correlate with random effects of the other level (Raudenbush & Bryk, 2002). Before starting the analyses, multicollinearity and the above assumptions were tested for each plausible value for each country data set and it was concluded that assumptions were met.

In applications before PISA 2015 application (like 2012, 2009, 2006), there were five plausible values, while in PISA 2015, students' science literacy levels were estimated with 10 different plausible values (PV1Fen-PV10Fen). In the HLM program, five output variables can be added, for example, the science literacy level plausible value in this study. However, since PISA 2015 application had 10 different plausible values, it was not possible to include ten values at the same time in the analysis. For this reason, as suggested in the PISA technical report, the mean values of the analyses obtained by establishing a model for each of these plausible values were examined (OECD, 2014). Estimations made by using only a single plausible value or by taking the average of the plausible value are not recommended as they cannot produce unbiased estimations and can cause critical errors in standard error estimations (OECD, 2014; Rutkowski et al., 2010; Von Davier, Gonzalez, & Mislevy, 2009).

In the analyses, data are centralized to minimize the inter- and intra-level high correlations (Level-1 and Level-2) (Raudenbush & Bryk, 2002). In this study, Level-1 variables centered around the group mean and Level-2 variables centered around the grand mean during the analyzes (Garson, 2013).

SPSS 22 statistical software package was used to organize the data, calculate the descriptive statistics, and transfer the organized data to the HLM 7.00 software. HLM 7.00 software was utilized for establishing and analyzing the hierarchical models. The statistical significance level was accepted as 0.05.

Results

Determination of the Difference between Schools in terms of Science Literacy Scores for Turkey and Singapore

The random coefficient One-Way ANOVA, one of the Hierarchical linear models, was used to test whether PISA 2015 science literacy scores showed a difference between schools in Turkey and Singapore. In PISA 2015, 10 possible scores were calculated for each student. The analyses were repeated for each possible score, and the average of the findings was taken. Accordingly, the model given below was established;

Level1:

$$(Y_{ij} \mid O_{PV}) = \beta_{0j} + r_{ij}$$

Level2:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

Combined model:

$$(Yij \mid O_{PV}) = \gamma_{00} + u_{0j} + r_{ij}$$

According to this model, the science literacy score of the student *i* in school *j* is called "Y_{ij}". In this study, the result (dependent) variable was defined as the student science literacy score. "β_{0j}" represents the mean science literacy score of school *j*. The "r_{ij}" value in the model indicates the random effect value of student *i* in school *j* (Lin, Tzou, Shyu, Hung, & Huang, 2006). On the other hand, the "γ_{00}" value in the model established for Level-2, is considered as the mean score of the means of the science literacy for each school for *j* number schools. "u_{0j}" shows the random effect of the j^{th} school (Anderson, 2012). Table 6 presents the findings related to the prediction of fixed effects according to the analysis results.

Table 6. The Estimation of Constant Effects Obtained from the Random Effect One-Way ANOVA Model

Country	**Fixed Affect**	**Constant**	**SH**	**t**
Turkey	for the Constant β_{0j} Average School Mean γ_{00},	418,03	4,32	96,65*
Singapore	for the Constant β_{0j} Average School Mean γ_{00},	556,15	4,67	118,99*

* p<.05

According to Table 6, the difference between the mean scores of the schools in terms of science literacy for Turkey and Singapore showed a significant difference from zero; in other words, there was a significant difference between the mean scores of the schools included in the analysis (t_{TR}=96,65, p<.001, t_{SGP}=118,99, p<.05).

However, the actual science literacy score for the Turkey sample was 418.03 ± 1.96 (4.32) with a 95% probability; in other words, it ranged between 409.56 and 426.50. The actual score range for the Singapore sample was determined to be 556,15 ± 1,96 (4,67). Correspondingly, the actual scores ranged from 565.30 to 547.00 with a 95% probability. Table 7 handles the results of the analysis related to the estimation of the variance components belonging to the model established for the first sub-objective of the study.

Table 7. The Estimation of Variance Components of The Random Effect One-Way ANOVA Model

Country		**Standard Deviation**	**Variance components**	**χ^2**	**sd**	**Explained %**
Turkey	School average, u0*j*	55,53	3084,27	5336,89	176	0,52
	Level-1 Effect, ri*j*	53,58	2871,51			
Singapore	School average, u0*j*	57,41	3328,66	2734,69	162	0,34
	Level-1 Effect, ri*j*	80,49	6478,51			

* p<.05

As is seen in Table 7, the variance between the science literacy mean scores of the schools for the Turkey sample was determined to be 3084.27. The variance of the students' science literacy scores within the framework of school means for Level-1 was calculated as 2871.51. On the other hand, school mean scores in terms of science literacy scores in Turkey were between 309.18 and 526.88 with a 95% probability according to 418.03 ± 1.96 $(3084.27)^{½}$ formula. According to this result, it can be said that the science literacy levels of the schools in Turkey covered a wide range. The variance between the mean values of the schools for the Singapore sample was determined as 3328.66. Also, the variance of science literacy scores of Singaporean students within the framework of school averages for the Level-1 was found as 6478.51. The plausible range of the mean scores of the schools for science literacy was determined as 669.23 and 443.07 with 556,15 ± 1.96 $(3328.66)^{½}$ formula. Although the upper and lower limits may be different for the two countries, the difference appears to be close to each other (217.7 for Turkey and 226.16 for Singapore).

In order to determine how much of the variance in science literacy scores of the students originate from the differences between schools, the index of explained variance ratio is obtained by comparing the model's τ00 (variance component) estimates for both levels (Hays, 1973; Hox, 1995). Accordingly, the explained variance value in β0j is calculated using the following equation.

$$\rho = \frac{\sigma_{u0}^2}{\sigma_{u0}^2 + \sigma_e^2}$$

Accordingly, the explained variance values for both countries were obtained by taking the variance values in Table 7 into account. The 52% of the differences (3084.27 / 3084.27 + 2871.51) observed in PISA 2015 Turkey science literacy scores stemmed from differences in the average science literacy scores between the schools. In other words, the differences in science literacy scores of the Turkish students come from school variables with a 52% probability and from student variables with a 48% probability. This difference between the schools in terms of science literacy scores was found to be coincidental (χ^2_{TR}=5336.891, sd=176).

According to the explained variance rates calculated for Singapore, it was determined that approximately 34% of the differences in the science literacy scores of PISA 2015 (3328.66 / 3328.66 + 6478,51) originated from the average science literacy scores between the schools. Accordingly, 34% of the differences in science literacy scores of Singaporean students were related to the school variables, while 66% were related to the student variables. When this result was compared to the 52% difference of Turkey indicating that much of the difference came from the differences between the schools, Singapore was found to have a lower percentage with 34%. This difference between the science literacy scores of Singaporean students was determined to be coincidental (χ^2_{SGP}=2734.689, sd=162).

Investigation of the Student Variables Associated with Science Literacy Scores for Turkey and Singapore

After obtaining the model created based on the school variables by including the student variables in the model accepted as the first level by Random Coefficient Model, these variables were analyzed whether they were a significant predictor or not (Raudenbush & Bryk, 2002). This model, established with first level variables, was considered as a simple linear regression model (Atar, 2010). This study aimed to determine which independent variables had a significant effect on science literacy. Accordingly, science self-efficacy, interest in science, enjoyment of science, teacher support in science class, research-based science teaching and learning applications, disciplinary climate in science class, and teacher-centered science teaching were included in the model as Level-1 variables. The model established accordingly is as follows:

Level-1 (Y_{ij}|O_{PV}) = β_{0j} + β_{1j} (science self-efficacy) + β_{2j} (interest in science) + β_{3j} (teacher support in science class) + β_{4j}(enjoyment of science) + β_{5j} (research-based science teaching and learning applications) + β_{6j} (disciplinary climate in science class) + β_{7j} (Teacher-centered Science Teaching)+ r_{ij}

Level-2

$\beta_{0j} = \gamma_{00} + u_{0j}$

$\beta_{1j} = \gamma_{10} + u_{1j}$

.

.

$\beta_{6j} = \gamma_{60} + u_{6j}$

Combined model (Yij| O_{PV}) = γ_{00} + u_{0j} + ($\gamma_{10} + u_{1j}$)*(science self-efficacy)+ ($\gamma_{20} + u_{2j}$)*(interest in science) + ($\gamma_{30} + u_{3j}$)*(teacher support in science class) + ($\gamma_{40} + u_{4j}$)*(enjoyment of science) + ($\gamma_{50} + u_{5j}$)*(research-based science teaching and learning applications) + ($\gamma_{60} + u_{6j}$)*(disciplinary climate in science class) + ($\gamma_{70} + u_{7j}$)* (Teacher-centered Science Teaching)+ r_{ij}

The method, suggested by Garson (2013), based on the test of significance of deviance value was used to test whether the model established with the Level-1 variables were significant. Accordingly, the level-1 model was determined to be statistically significant for both Turkey and Singapore samples ($\chi 2_{TR}$=765.178; p<0.001; $\chi 2_{SGP}$=270.401; p<0.001). Table 8 presents the results of the analysis conducted to determine whether the science related student variables for Turkey and Singapore samples were a significant predictor of science literacy.

Table 8. The Estimation of Constant Effects Related to the Level-1 Random Coefficient Model for Singapore and Turkey samples

	Constant effects	**Coefficients**	**Standard error**	***t-ratio***	**s.d.**
Turkey	Overall achievement, γ_{00}	417,882	4,329	96,545*	176
	Science self-efficacy, γ_{10}	-0,718	0,174	-4,134*	
	Interest in science, γ_{20}	0,654	0,219	2,995*	
	Teacher support in science class, γ_{30}	1,546	0,230	6,739*	
	Enjoyment of science, γ_{40}	-0,769	0,252	-3.057*	
	Research-based science teaching and learning applications, γ_{50}	1,521	0,146	10,428*	
	Disciplinary climate in science class, γ_{60}	0,383	0,246	1,421	
	Teacher-centered science teaching, γ_{70}	1,025	0,291	3,524*	

Table 8. Continued

	Constant effects	Coefficients	Standard error	*t-ratio*	s.d.
Singapore	Overall achievement, γ_{00}	556,20	4,682	118.760*	162
	Science self-efficacy, γ_{10}	-2,348	0,268	-8.762*	
	Interest in science, γ_{20}	1,185	0,377	3.146*	
	Teacher support in science class, γ_{30}	4,778	0,428	11.164*	
	Enjoyment of science, γ_{40}	-0,278	0,424	-1.052	
	Research-based science teaching and learning applications, γ_{50}	1,998	0,276	7.237*	
	Disciplinary climate in science class, γ_{60}	4,720	0,379	12.461*	
	Teacher- centered science teaching, γ_{70}	1,236	0,496	2.494*	

*p<.05

As is seen in Table 8, science self-efficacy, interest in science subjects, teacher support in science class, research-based science teaching and learning applications, and teacher-centered science teaching variables were determined as a significant predictor of science literacy for both countries ($p < 0.05$). Accordingly, a one-unit increase in students' science self-efficacy levels brought about a 0.718 point decrease for Turkey and a 2.348 point decrease for Singapore in science literacy scores. A one-unit increase in the level of interest in science resulted in an increase of 0.654 points for Turkey and an increase of 1.185 points for Singapore in science literacy scores. On the other hand, a one-unit increase in teacher support in science class variables caused a 1.546 and 4.778 point increase in science literacy scores for Turkey and Singapore, respectively. It can be seen that teacher support in science class was more effective in Singaporean students' science literacy scores compared to those of Turkish students. A one-unit increase in research-based science teaching and learning applications variable led to a 1.521 point increase for Turkish students and 1.998 points for Singaporean students in terms of students' science literacy scores. A one-unit increase in teacher-centered science teaching variables resulted in a 1.025 points increase for Turkish students and 1.236 points for Singaporean students in terms of students' science literacy scores.

Unlike Singaporean students, the enjoyment of science variable was determined to be a significant predictor of science literacy scores for Turkish students ($t = -3,057$, $p < .01$). It was found that a one-unit increase in the enjoyment of science scores of Turkish students led to a 0.769 point decrease in science literacy scores. For Singapore, the same increase in the same score brought about a 0.28 point decrease in science literacy scores. However, it was found that the enjoyment of science variable was not a significant predictor of science literacy for the Singapore sample ($t = -1,052$, $p > .05$). The negative correlation between the enjoyment of science and science literacy scores for both countries and the significance of this correlation for Turkey was quite remarkable.

Unlike the Turkey sample, the variable of "disciplinary climate in science classes" was observed to significantly predict science literacy in the Singapore sample ($t = -12.46$, $P < .05$). A one-unit increase in the disciplinary climate in the science class variable brought about a 4.729 point increase in terms of science literacy scores for the Singapore sample. It can be said that this is the second most effective variable on the science literacy scores of Singaporean students after the teacher support in the science class variable. However, the variable of "disciplinary climate in science" did not predict science literacy for Turkish students significantly ($t = 1.42$, $p > .05$). The estimated values of the variance components for the Random Coefficients Model created for variables predicting student-level science literacy scores are presented in Table 9.

Table 9. The Estimated Variance Components for Level-1 Random Coefficient Model

	Coincidental effects	Standard Deviation	Variance Components	s.d.	$\chi 2$
Turkey	School average, u_{0j}	55,71909	3104,77172	152	5612,26029
	Level-1 effect, r_{ij}	51,39233	2641,35666		
Singapore	School average, u_{0j}	58,13295	3379,77446	160	3289,08325
	Level-1 effect, r_{ij}	73,21064	5359,83637		

* p<.05

Table 9 shows findings related to the variance of science literacy scores obtained as a result of including level-1 variables in the model and the significance test of the random effect of the variance for the school level for both countries. Accordingly, the variance of science literacy scores obtained as a result of including student-level variables in the model for Turkey sample was calculated as 3104.77. However, it can be interpreted that approximately 54.03% of the change in science literacy scores (3104.77 / 3104.77 + 2641.36) obtained as a result of student-level variables in the model was caused by the differences between schools. Accordingly, when the student-level variables were included in the model, it can be said that there was a 2% increase in the amount of the explained variance. Also, 54% of the difference in Turkish students' science literacy scores was found to be coincidental ($\chi 2TR=3289.08$, df=160, p<.01).

When the student-level variables were added to the model for Singapore, the variance in the students' science literacy scores was found to be 3379.77. At the same time, approximately 38.67% (3379.77 / 3379.77 + 5359.83) of the difference in the science literacy scores established by the related model was due to the differences between schools. However, with the inclusion of student-level variables in the model, an approximately 5% increase was observed in the explained variance of students' science literacy performances. The 39% difference in science literacy scores obtained when the student-level variables were added to the model was coincidental ($\chi 2=5612.26$, df=152, p<.01).

Investigation of the School Variables Associated with Science Literacy Scores for Turkey and Singapore

In line with the third sub-objective of the study, the model established to determine the science-related school variables resulting in a difference between schools and predicting science literacy scores of the schools participating in PISA 2015 application in Turkey and Singapore and the result of the analyses were included under this title. The science-related school variables handled in the study were "the proportion of science teachers at schools" and "Proportion of 4 years of education or more to all science teachers "

Level1

$(Y_{ij} | O_{PV}) = \beta_{0j} + r_{ij}$

Level2

$\beta_{0j} = \gamma_{00} + \gamma_{01}$ (Proportion of science teacher to all teacher) + γ_{01} (Proportion of 4 years of education or more to all science teachers) + u_{0j}

Combined model $(Yij| O_{PV}) = \gamma_{00} + \gamma_{01}$ (Proportion of science teacher to all teacher) + γ_{01} (Proportion of 4 years of education or more to all science teachers) + $u_{0j} + r_{ij}$

Table 8 presents the results of the analysis obtained from the model established at the school level as shown above.

Table 10. The Estimation of Constant Effects for Level-2 Random Coefficients Model

	Constant effects	Coefficients	Standard Error	*t*-ratio	s.d.
Turkey	Overall achievement average, γ_{00}	418.076	4,034	103.640*	174
	Proportion of science teacher to all teacher, γ_{01}	345.274	66,786	5.170*	174
	Proportion of 4 years of education or more to all science teachers , γ_{02}	493.147	10,006	0,4930	174
Singapore	Overall achievement, γ_{00}	555.898	4,431	125,463*	160
	Proportion of science teacher to all teacher, γ_{01}	432.355	93,277	4,635*	160
	Proportion of 4 years of education or more to all science teachers , γ_{02}	156.180	24,156	0,6463	160

*p<.05

As shown in Table 10, proportion of science teacher to all teacher, which was one of the school-level variables for both Turkey and Singapore, was found to predict science literacy significantly. (t_{TR}=5.170, p<.01; t_{SGP}=4.635, p<.01). A 1% increase resulted in a 3.45 and 5.56 point increase in science literacy scores for Turkey and Singapore, respectively. However, proportion of 4 years of education or more to all science teachers variable was not found to be a significant predictor of science literacy (t_{TR}=0.4930, p>.01; t_{SGP}=0.6463, p>.01).

Table 11. Estimation of Variance Components for Level-2 Random Coefficients Model

	Coincidental effects	Standard Deviation	Variance Components	s.d.	$\chi 2$
Turkey	School average, u_{0j}	51,563	2658,880	174	4430,633*
	Level-1 average, r_{ij}	53,590	2872,064		
Singapore	School average, u_{0j}	54,474	2967,716	160	2421,866*
	Level-1 average, r_{ij}	80,478	6476,766		

* p<.05

As is seen in Table 11, the variance of science literacy scores of the students in the Turkey sample was calculated as 2658.880 when the level-2 variables were added to the model. It was determined that the amount of variance explained in science literacy scores by adding school-level variables to the model decreased to nearly 48.08% [2658.88 / (2658.88 + 2872.064)]. Accordingly, when the school-level variables were added to the model, an approximately 4% decrease was found in the explained variance of students' science literacy performances. The difference in science literacy scores stemmed from school variables at 48% and this difference emerging between schools was coincidental (χ2TR=4430.63, df=174, p<.01).

According to Table 11, the variance of science literacy scores of the students for the Singapore sample was estimated to be 2967,716 when the levels2 variables were included in the model. However, for the same model, the explained variance of the difference in students' science literacy scores was calculated as 31.42% [2967,716 / (2967,716 + 6476,766)]. In other words, when school variables were added to the model, a nearly 3% decrease was observed in the explained variance of students' science literacy performances. This 31% variation in science literacy scores was found to be coincidental (χ2SGP=242.866, df=160, p<.01).

Investigation of the School and Student Variables together Associated with Science Literacy Scores of Turkey and Singapore for PISA 2015

In line with the fourth sub-objective of the study, a model where the intersections and slopes were dependent variables was created as a result of including variables in the analysis together which predict the student and school level science literacy significantly (Raudenbush & Byrk, 2002). The model established for Turkey sample:

Level1

$(Y_{ij} | O_{PV}) = \beta_{0j} + \beta_{1j}$ (Science self-efficacy) + β_{2j} (Interest in science) + β_{3j} (Teacher support in science class) + β_{4j}(Enjoyent of science) + β_{5j} (Research-based science teaching and learning applications) + r_{ij}

Level2

$\beta_{0j} = \gamma_{00} + \gamma_{01}$ (Proportion of science teacher to all teacher) + u_{0j}

$\beta_{1j} = \gamma_{10} + \gamma_{11}$ (Proportion of science teacher to all teacher) + u_{1j}

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$\beta_{6j} = \gamma_{50} + \gamma_{51}$ (Proportion of science teacher to all teacher)+ u_{5j}

The model established for Singapore sample;

Level1

$(Y_{ij} | O_{PV}) = \beta_{0j} + \beta_{1j}$ (Science self-efficacy) + β_{2j} (Interest in science) + β_{3j} (Teacher support in science class) + β_{4j} (Research-based science teaching and learning applications) + β_{5j} (Disciplinary climate in science class) + r_{ij}

Level2

$\beta_{0j} = \gamma_{00} + \gamma_{01}$ (Proportion of science teacher to all teacher) + u_{0j}

$\beta_{1j} = \gamma_{10} + \gamma_{11}$ (Proportion of science teacher to all teacher) + u_{1j}

$\beta_{6j} = \gamma_{50} + \gamma_{51}$ (Proportion of science teacher to all teacher)+ u_{5j}

While the level-1 model for both groups showed a difference, the level-2 model was the same. The results of the analysis on the estimation of the constant effects of these models are given in Table 12.

Table 12. The Estimation of Constant Effects related to the Full Model

	Constant effects	Coefficients	Standard Error	*t*-ratio	s.d.
Turkey	Overall Achievement, γ_{00}	417,933	4,029	103,730*	175
	Proportion of science teacher to all teacher, γ_{01}	346,074	66,690	5,190*	175
	Science self-efficacy, γ_{10}	-0,723	0,175	-4,131*	175
	Interest in science, γ_{20}	0,663	0,219	3,031*	175
	Teacher support in science class, γ_{30}	1,566	0,229	6,830*	175
	Enjoyment of science, γ_{40}	-0,797	0,251	-3.178*	175
	Research-based science teaching and learning applications, γ_{50}	1,516	0,146	10,388*	175
	Teacher- centered science teaching, γ_{60}	1,077	0,290	3,715*	175
Singapore	Overall Achievement Average, γ_{00}	555,804	4,426	125.597*	161
	Proportion of science teacher to all teacher, γ_{01}	428,185	91,010	4.705*	161
	Science self-efficacy, γ_{10}	-2,352	0,269	-8.757*	162
	Interest in science, γ_{20}	1,168	0,375	3.116*	162
	Teacher support in science class, γ_{30}	4,825	0,425	11.349*	162
	Research-based science teaching and learning applications, γ_{40}	1,960	0,264	7.417*	162
	Disciplinary climate in science class, γ_{50}	4,737	0,377	12.575*	162
	Teacher- centered science teaching, γ_{60}	1,346	0,456	2.957*	162

* p<.05

All of the first and second level variables, which were significant predictors of science literacy related to the estimation of constant effects of the Full Model shown in Table 12, were included in the analysis. Accordingly, the proportion of science teachers variable was determined to be a significant predictor of science literacy at the school level for both Turkey and Singapore samples (tTR=5.19, p<.01; tSGP=4,705, p<.01). When the results of the analysis were analyzed in terms of student variables, the variables for science self-efficacy, interest in science, enjoyment of science, teacher support in science classes, research-based science teaching and learning applications, and teacher-centered science teaching were found to be a significant predictor of science literacy scores of the students for Turkey (p <. 01). The student-level variables for science self-efficacy, interest in science, teacher support in science classes, research-based science teaching and learning applications, the disciplinary climate in science classes, and teacher-centered science teaching were found to predict the science literacy scores significantly for Singapore sample (p <.01). The results of the analysis relating to the estimation of variance components for the full model are given in Table 13.

Table 13. The Estimation of Variance Components Related to the Full Model

	Coincidental effects	Standard Deviation	Variance components	s.d.	$\chi2$
Turkey	School average, u0*j*	51,634	2666,267	152	4666,130*
	Level-1 effect, ri*j*	51,534	2655,968		
Singapore	School average, u0*j*	54,750	2997,863	159	2907,212*
	Level-1 effect, ri*j*	73,460	5396,466		

* p<.05

As is shown in Table 11, the variance of science literacy scores of the schools according to the full model for the Turkey sample was estimated to be 2666.267. The difference between full model-based science literacy scores obtained by including student and school variables to the model was calculated as approximately 50% [2666.267 / (2666.267 + 2655.968)]. Accordingly, an approximately 2% decrease was observed in the explained value of the variance as a result of the inclusion of both level variables in the model.

According to the findings of the analysis of the full model in Table 9 for the Singapore sample, the variance in the science literacy scores was estimated at 2997.863. The explained variance of the science literacy scores was calculated as nearly 36% [2997.863 / (2997.863 + 5396.466)] by adding the first and second level variables to the model. According to this, it can be said that the explained variance ratio of Singaporean students' science literacy scores decreased by 2%.

Discussion, Conclusion and Suggestions

The data and findings obtained from international educational research, which provide very important outcomes relating to the education systems of countries, are considered very significant in terms of guiding the countries' educational reforms (Ercikan et al., 2015; McGraw, 2008; Niemann et al., 2017; Sjøberg, 2015). The results obtained are meaningful not only to show the position of a given country among other countries but also to set the education systems of successful countries an example for other countries. Accordingly, there is a need for research-based data obtained from this kind of research. PISA is considered as one of the largest educational surveys. While tests are carried out in the areas of science and mathematics literacy as well as reading skills in PISA application, these tests are supported through student, school, and parent surveys. The focus of PISA 2015 was science literacy. However, as mentioned before, the data collected do not only cover cognitive areas but also affective areas. Thus, it is possible to evaluate student performance in every aspect. The data obtained were observed to show a hierarchical structure in terms of countries, schools, classes, students, etc.

This study aimed to determine the variables predicting science literacy performance, which was among the student and school-level variables in the Turkey and Singapore samples included in the study that were directly related to science and considered significant by OECD. According to the findings obtained from the study, the results obtained for both countries were discussed in accordance with the sub-objectives of the study.

Relating to the question "Is there a significant difference between the schools in terms of science literacy scores?", a significant difference was found between the schools in terms of science literacy for both countries. The difference in science literacy scores between the schools in Turkey was quite high compared to the Singapore sample. Acar and Öğretmen (2012) reported that the science performance of students varied by schools according to PISA 2006 application for Turkey sample. The reason why there were fewer differences between schools in Singapore was that the adoption of a holistic educational approach and a much less number of school types in secondary education compared to Turkey.

According to the findings obtained to determine the student-level variables showing a significant relationship with students' science literacy scores, the variables making up the difference between the two countries such as enjoyment of science for Singapore and disciplinary climate in science class for Turkey were not a significant predictor of science literacy. In addition to these, interest in science, research-based science teaching and learning applications, teacher support in science class, and science self-efficacy variables were determined as a significant predictor of science literacy for both countries.

Studies on variables seen as a predictor of science literacy were discussed separately in light of the literature. Some studies found a positive relationship between the variables of interest in science and science literacy (Baumert & Köller, 1998; Osborne et al., 2003), whereas Albayrak (2009) determined a negative relationship between the two variables according to the data from PISA 2006. One of the aims of teaching science is to increase students' interest in science (Lind, 2005). Similarly, this objective was also included in the Ministry of Education, Science and Technology course curriculum (MoNE, 2005). Interest is seen as a motivating prerequisite for learning and teaching in students (Hidi, Renninger, & Krapp, 2004). In this study, a positive relationship was found between science literacy and interest in science for both countries. This relationship can be explained by the fact that the science teaching program involves the aim of increasing interest in science.

Inquiry-based science teaching and learning practices which are seen as the main component of science literacy increases science literacy performance (Anagün, 2011; Blanchard et al., 2010; Chiang et al., 2014; Furtak et al., 2012; Lee et al., 2005; Lynch et al., 2005; Minner et al., 2010; Tal et al., 2006; Wolf & Fraser, 2008). Another objective of science teaching is to educate inquisitive and questioning individuals in line with the constructivist approach (Lind, 2005; MoNE, 2005). Accordingly, science teaching is carried out in accordance with the relevant objectives based on research. Thus, research-based teaching, which is an important goal of the process, increases both science achievement (Akpullukçu, 2011; Sakar, 2010) and science literacy.

With this study, it was concluded that the science self-efficacy variable was a significant predictor of science literacy for both countries. The examination of the literature indicated that a similar relationship was revealed by many studies (Albayrak, 2009; Anderman & Young, 1994; Britner & Pajares, 2006; Çalışkan, 2008; Kartal Kula & Kutlu, 2017; Lau & Roeser, 2002; Pajares, 1996; Palmer, 2006; Usta, 2009). This may be associated with the fact that self-efficacy is seen as the most important predictor of student performance in education and has an even much higher predictor than all other variables.

Another variable determined to be a significant predictor in both countries is the teacher support variable in science class. In addition to the positive relationship between teacher support and academic achievement, this variable has positive effects on other variables that increase academic achievement. For example, increased teacher support contributes positively to variables such as interest, motivation, and internal effort. Studies supporting this finding are also frequently found in the literature (Cornelius-White, 2007; Den Brok et al., 2005; Dietrich et al., 2015; Furrer & Skinner, 2003; Hattie, 2008; Ladd & Burgess, 2001; Murray, 2009; Roorda et al., 2011; Wentzel et al., 2010). Teacher-centered science teaching, which is included in PISA, focuses on a teaching process in which students are more passive, unlike inquiry-based science teaching and learning practices. Besides, similar to the results of this study, the presence of a positive relationship between teacher-centered teaching and student performance has been demonstrated by studies (Schroeder et al., 2007; Wise, 1996; Yayan & Berberoğlu, 2004). With teacher-centered teaching, the teacher is said to both lecture and be in interaction with students. The teacher also gives the necessary support that students need for their learning. However, the fact that students are more accustomed to teacher-centered teaching makes them feel more comfortable in this kind of teaching. In addition to a study in which a positive relationship was found between student-centered instruction and students' perception of failure (Ceylan & Berberoğlu, 2007), a negative relationship between student-centered teaching and science performance was another remarkable finding (Aypay et al., 2007; Kalender & Berberoğlu, 2008). These findings were found to support the outcome that teacher-centered teaching was more effective in science teaching. Students can be said to be affected negatively by student-centered science teaching in terms of both affective aspects and performance.

One of the variables that showed a difference in terms of predicting science literacy in Singapore and Turkey samples was "the enjoyment of science" variable. The examination of the findings found in the related literature about the variable in question indicated that the existence of a positive correlation between the variable and science literacy was laid out by studies conducted on the samples of many countries (Grabau & Ma, 2017; Areepattamannil & Kaur, 2013; Lavonen & Laaksonen, 2009; Lam & Lau, 2014; Ng et al., 2012; Tighezza, 2014; Jen et al., 2013; Tsai & Yang, 2015). On the other hand, this relationship between the two variables was determined to be negative particularly in the samples of Middle Eastern and North African countries (Bouhlila, 2011). Accordingly, the finding that the relationship between the enjoyment of science and science literacy varied by countries was supported by this study. Besides, it is noteworthy that there was a negative relationship between the enjoyment of science and science literacy for the samples of both countries. However, while the enjoyment of science was a significant predictor of science performance for Turkey, it was not significant for Singapore. This can be explained by the relationship between self-learning and enjoyment of science. Enjoyment of science is seen as a driving force in self-learning (Shernoff et al., 2003). However, students perform much better with teacher support and in teacher-centered teaching than in self-learning expected from student-centered instruction. The fact that student-centered education is used more commonly and appropriately in Singapore compared to Turkey can be considered as the source of the difference between the two countries in terms of "the enjoyment of science" variable.

Disciplinary climate, which is a variable showing a difference in terms of Singapore and Turkey, has been found to show a positive relationship with science literacy in studies on PISA data for many countries (Akyüz & Pala, 2010; Chi et al., 2018; Güzel, 2006; OECD, 2004). Positive disciplinary climate has been observd to increase the achivement of students (Arum & Velez, 2012; Cheema & Kitsantas, 2016; Elliott & Phuong-Mai, 2008; Fan, 2012; Figlio, 2007; Frempong et al., 2012; Gamoran & Nystrand, 1992; Jenkins & Ueno, 2017; Hamre & Pianta, 2001; Hughes et al., 2012; Lassen et al., 2006; Ma, Jong, & Yuan, 2013; Ma & Williams, 2004; Marks, 2010; Marzano & Marzano, 2003; McCormick et al., 2013; Mikk et al., 2016; Miller, 1996; Ning et al., 2015; Roorda et al., 2011; Sanders & Jordan, 2000). The positive relationship between disciplinary climate and science literacy was in line with the literature for both countries, whereas this variable was found to be not a significant predictor for Turkey sample. One of the reasons why Turkey was much less successful in PISA 2015 compared to Singapore was that the disciplinary climate, which is positively related to science performance, was not a significant predictor for Turkey. In other words, the fact that disciplinary climate was not a significant predictor of science literacy for Turkey can be explained by the fact that the success of Turkey in PISA 2015 was much less than that of Singapore.

The examination of school-level variables, which have a significant relationship with students' science literacy scores, indicated that the proportion of science teacher to all teacher in schools for both countries was a significant predictor of science literacy. There is no research into the relation of science teacher ratio with science literacy. In the study, the variables discussed at school level were mostly school climate, quality of educational resources, extra activities offered to students in school, school climate affected by teacher-related factors, quality of physical resources in socio-economic level, student/teacher ratio, class size, and school size (Acar & Öğretmen, 2012; Marks et al., 2006; Özkan, 2015; Acar & Öğretmen, 2012). A study which was carried out on PISA 2003 and 2012 Turkey data showed that math teacher ratio in schools was a significant predictor of math literacy (Özberk et al., 2017). The fact that the proportion of science teachers is a significant predictor of science literacy can be explained by the positive relationship between science performance and teacher support and teacher-centered teaching. As the proportion of science teachers increases, teacher support will increase, as well. It is noteworthy that the ratio of science teachers who have received proportion of 4 years of education or more to all science teachers was not a significant predictor of science literacy for both countries. In both countries, the teacher education program is carried out at the undergraduate level may have been related to the fact that the proportion of science teachers educated for over four years is not a significant predictor. In other words, the fact that the majority of teachers have been trained for four years or more may have caused the related variable to not predict science performance significantly. In this study, the school-level variables were found to be not discussed in previous studies. Accordingly, this study was the first study in this sense. With the addition of school variables to the model, the variance rate explained in both countries was found to decrease.

The model which involved both level variables (school and student) together that were determined as the significant predictor of science literacy and the models comprising student and school variables separately yielded the same results. The student-level variables for Turkey such as science self-sufficiency, interest in science, enjoyment of science, teacher support in science class, research-based science teaching and learning applications, and teacher-centered science teaching were determined as significant predictors of science literacy scores of the students. On the other hand, for Singapore, among the student-level variables, science self-sufficiency, interest in science, teacher support in science class, research-based science teaching and learning applications, the disciplinary climate in science classes, teacher-centered science teaching were found to predict science literacy scores of the students. Moreover, "the proportion of science teachers" variable was found to significantly predict science literacy both in Turkey and Singapore at the school level.

According to the results obtained, the following recommendations were made for the researchers and practitioners:

- The reasons for the quite high difference between the schools in terms of science literacy compared to the Singapore sample, which is an important outcome for the Turkey sample, should be investigated and necessary applications should be developed to reduce this difference.
- The reasons for the insignificant relationship between science literacy and the variables such as the enjoyment of science for Singapore and disciplinary climate in science class for Turkey should be investigated by handling the factors affecting the related variables.
- The reasons why the proportion of science teachers with 4 years of education or more/total science teachers was not a significant predictor of science literacy performance for both countries should be investigated, and a similar comparative study should be conducted on other international applications.
- While similar studies can be repeated for mathematics literacy and reading skills, studies with three-level models can be conducted by adding country-level variables. Similar studies can be repeated with different schooland student variables.
- As discussed in this study, the findings of other PISA applications or the results of other international surveys such as TIMMS and PIRLS can be compared by considering the variables directly related to science.

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