



This is an open access article under the  
Creative Commons Attribution 4.0  
International License

# THE EFFECTS OF INFORMATION AND COMMUNICATION TECHNOLOGY ENGAGEMENT FACTORS ON SCIENCE PERFORMANCE BETWEEN SINGAPORE AND TURKEY USING MULTI-GROUP STRUCTURAL EQUATION MODELING

**Batuhan Özkan,  
Fatma Noyan Tekeli**

## Introduction

The Program for International Student Assessment (PISA) conducted by the OECD in three-year cycles is an international large-scale program that measures 15-year-old students' knowledge and skills in reading, mathematics, and science. PISA compares the quality and equity of education across countries, and the results obtained are used by educators and politicians in determining appropriate education policies and practices (OECD, 2019a). In each cycle of the research, a subject is chosen as the main area. Like the previous cycles, the PISA 2018 assessment covered the areas of reading, mathematics, and science, but the core area was reading literacy.

In recent years resources related to ICT have become accessible to students both at home and at school and have gained a large place in modern society. Due to the importance of ICT, an optional ICT familiarity questionnaire about ICT availability, ICT skills and ICT use has been included in each cycle of PISA since 2000 (Kunina-Habenicht & Goldhammer, 2020). With the change in PISA 2015, ICT engagement questionnaire was added to PISA's ICT familiarity survey as a new structure and this scale was also included in PISA 2018. ICT engagement scale has been improved by both intrinsic and extrinsic motivation derived from the theory of self-determination (Deci & Ryan, 2000). ICT engagement scale has four factors: 1. Interest in ICT which is the intrinsic motivation of using products related to ICT (Zylka et al., 2015); 2. Perceived ICT competence, students' ICT-based knowledge and skills that can be used to perform ICT-related tasks (Meng et al., 2019); 3. Perceived autonomy in using ICT, perceived control and independence of an individual in using ICT; 4. Social Relatedness in using ICT, the measure of an individual communicating and interacting with others using ICT (Kuger et al., 2016; Zylka et al., 2015)

ICT engagement scale is a fairly new scale. While reviewing the literature, it was noticed that the early studies leading to this scale originated from the



JOURNAL  
OF BALTIC  
SCIENCE  
EDUCATION

ISSN 1648-3898 /Print/  
ISSN 2538-7138 /Online/

**Abstract.** *Information and Communication Technology (ICT) engagement, as a multidimensional construct, plays an increasingly important role in education. The main purpose of this research was to explore the effects of ICT engagement factors on science performance across Singapore and Turkey conditional to the sufficient degree of measurement invariance of ICT engagement scale. The multi-group confirmatory factor analysis results demonstrated strong factorial invariance of ICT engagement scale across Singapore and Turkey, so we were able to use ICT engagement scale to meaningful and valid comparisons between these countries. After obtaining measurement invariance, a multi-group structural equation modeling was used for the comparison of the effects of ICT engagement factors on student's performance of science between these two countries. While interest in ICT, perceived ICT competence and perceived autonomy in using ICT have significant positive direct effect on science performance in both countries, the direct effect of social relatedness in using ICT on science performance is negative in both Singapore and Turkey. Also, when compared with Singapore, the effects of all ICT engagement constructs on student's performance are higher in Turkey.*

**Keywords:** *ICT engagement, measurement invariance, multi-group SEM, science performance, PISA 2018*

**Batuhan Özkan, Fatma Noyan Tekeli**  
Yildiz Technical University, Turkey



use of ICT in school and in home (Meng et al., 2019). Researchers obtained mixed results about the effect of using computer and technology on students' success (Agasisti et al., 2020; Chen & Wang, 2013; Eickelmann et al., 2016; Lei & Zhao, 2007; Liemb et al., 2014; Notten & Kraaykamp, 2009; Thiessen & Looker, 2007; Xin & Zhou, 2010). For example, Thiessen and Looker (2007) showed that intensive computer use in Canada was negative relationship with students' reading performance whereas Xin and Zhou (2010) showed that computer technology use increased students' performance. Using PISA 2012 data from 15 European countries, the study showed that intensive computer use in homework negatively affected test scores in all areas (Agasisti et al., 2020). It could be argued that the first studies about ICT in the literature were about the effect of computer or internet use on success in school and in home (Meng et al., 2019). These studies revealed the need for developing an ICT engagement construct. Later studies focused on development of construct related to ICT (De Wit et al., 2012; Janneck et al., 2013; Senkbeil & Ihme, 2017). Zylka et al. (2015) proposed a new ICT engagement scale which was more motivation and meta-cognition perspective of ICT related constructs. ICT engagement scale was adapted to the four-dimensional structure in PISA 2015. In recent studies, ICT engagement has been considered as a multidimensional construct and its effect on academic achievement has been explored. Different results were obtained (Cheema & Zhang, 2013; Hu et al., 2018; Lee & Wu, 2012; Luu & Freeman, 2011). For example, perceived ICT autonomy had a positive effect on achievement (Cheema & Zhang, 2013). According to the study conducted by Lee and Wu in 2012, interest in ICT and perceived ICT competence were positive predictors of reading achievement.

The ICT engagement scale, developed in PISA 2015 and used in PISA 2018, is a relatively new assessment tool. There were only two studies (Meng et al., 2019; Ma & Qin, 2021) exploring the validity of this scale across countries. It was necessary to explore the measurement invariance of this scale to make valid comparisons between different groups (Măță et al., 2020). Measurement invariance is a property that indicates a measurement tool (a questionnaire in the case of survey research) measures the same concept in various subgroups in the same way (Davidov et al., 2014). The measurement issues of the newly ICT engagement scale need to be further explored. This research was devoted to explore the effects of ICT engagement factors on performance of science between Singapore and Turkey using Multi-group Structural Equation Modeling (Multi-group SEM) analysis. The first step was composed of the analyzes for configural, metric and scalar invariance of ICT engagement scale of PISA 2018 across Singapore and Turkey using Multi-group Confirmatory Factor Analysis (Multi-group CFA). As the ICT engagement scale provided acceptable invariant, effects of ICT engagement factors on students' science performance were compared between Singapore and Turkey in the second step.

### *Research Problem*

In this research, Singapore and Turkey were chosen to compare. Students from these two countries completed the optional ICT engagement form in PISA 2018. These two countries represent different education systems and different success in PISA. Singapore education system can offer a customized curriculum for student groups created according to their technical and social characteristics in the same school, whereas Turkey education system offers the same curriculum for all students (Kilic Depren, 2020). Singapore and Turkey had different science performance in PISA 2018. According to PISA 2018 results, the average science performance of 15-year-olds in Turkey was 468 points and it was less than 489 points which was the average for OECD countries participating in the same cycle. Turkey's change in performance of science between PISA 2015 and 2018 indicated one of the strongest increases among participating countries and economies. In Singapore, whose average in science performance was one of the highest among countries and economies participating in PISA, the average score was 551 (OECD, 2019c). Singapore has national plans for ICT integration and implementation covering the educational environment and resources. Turkey's ICT policy also aims at improving both ICT infrastructure and capacity of stakeholders according to "Information Society and Action Plan (ISAP) for 2014-2018" prepared by The Ministry of Development (MoD) of Turkey. Considering that both countries are focused on the same goal in terms of ICT, Singapore, with the highest science achievement, and Turkey, with the highest increase in science performance between PISA 2015 and 2018, were selected to compare the effectiveness of ICT policy.

### *Research Focus*

In this research, the measurement invariance of the ICT engagement scale was examined across Singapore and Turkey. If a sufficient degree of invariance is achieved (i.e., scalar invariance), then the effects of ICT engage-



ment factors on performance of science could be compared across these two countries. Specifically, the following research questions were addressed:

1. To what extent does the ICT engagement scale show invariance across Singapore and Turkey? (Multi-group CFA)
2. If a sufficient level of invariance can be established, how do the effects of ICT engagement factors on student science performance differ by Singapore and Turkey? (Multi-group SEM)

## Research Methodology

### *General Background*

PISA evaluates to what extent 15-year-old students who are about to complete their compulsory education have acquired the knowledge and skills necessary for them to adapt to modern societies. This assessment examines the extent to which students can draw conclusions from the information they have acquired and to what extent they can apply this knowledge in school and out-of-school, rather than whether students can reproduce information. The PISA 2018 evaluation is the seventh since the program started in 1997. In the program, which is carried out and developed in cooperation between the governments of OECD countries and partner countries/economies, evaluations focusing on basic areas such as reading, mathematics and science are carried out in three-year cycles. The main assessment area in PISA 2018 was reading (Mathematics became the main field in 2003 and 2012, and science was the main field in 2006 and 2015) (OECD, 2019b).

### *Participants*

The data were obtained from the PISA 2018 database which is open access and freely available. Missing values were excluded from the analysis. In Turkey 6531 students participated from 189 schools with 3396 being female 49.3% and 3494 being male 5.7%. In Singapore 6390 students from 166 schools were tested; 3277 were female 49.1 % and 3399 were male 5.9 %. A large part of the Singapore and Turkey data consisted of grade 10 students (respectively 91.3% and 77.8%).

### *Instrument and Procedures*

Zylka et al. (2015) introduced ICT engagement scale as a motivation and meta-cognition of ICT literacy. First, the ICT engagement scale had a five-dimensional construct, and then it was revised to a four-dimensional construct. The revised ICT engagement scale has four factors: interest in ICT, perceived ICT competence, perceived autonomy in using ICT and social relatedness in using ICT. ICT engagement scale consists of 4 factors and 21 items in PISA 2018.

All items were measured by 4-point Likert scale. This scale ranged from 1 for strongly disagree to 4 for strongly agree (Zylka et al., 2015). Higher values of 4-point scale show better ICT engagement. The means of the items ranged from 2.16 to 3.17 and all were higher than the midpoint of the 4-point scale, 2.0. Descriptive statistics and internal consistency of the scale (Cronbach's alpha) are presented in Table 1. Cronbach's alpha coefficients of four factors for each of the two countries ranged from .846 to .876 and were sufficiently high.

Interest in ICT (IICT): IICT defines an individual's long-term choice about the tasks, topics, or activities related to ICT. Interest in ICT is expected to influence behavior related to ICT and produce positive emotions, learning and performance results (Goldhammer et al., 2016). In PISA 2018, this subscale had six items. Internal consistencies of interest in ICT were .792 for the Singapore data and .860 for Turkey data.

Perceived ICT competence (PICT): PICT is the belief of individuals about their knowledge with respect to ICT and to use this knowledge (Goldhammer et al., 2016). This subscale consisted of five items. Internal consistencies of perceived ICT competence were .806 for the Singapore data and .872 for Turkey data.

Perceived autonomy in using ICT (PAICT): PAICT projects the individual's perceived control and self-management in activities related to ICT (Goldhammer et al., 2016). It is expected to experience a sense of control over by using ICT tools and to associate their success in using these tools with their own abilities rather than other reasons (Kunina-Habenicht & Goldhammer, 2020). This subscale consisted of five items. Internal consistencies of perceived autonomy in using ICT were .867 for the Singapore data and .874 for Turkey data.

Social relatedness in using ICT (SRICT): It expresses the need for the individual to make ICT a subject in com-



munication and interaction with others, and also to share their interest, knowledge, experience and activities with others (Goldhammer et al., 2016). This subscale consisted of five items. Internal consistencies of social relatedness in using ICT were .850 for the Singapore data and .868 for Turkey data.

**Table 1**  
*Descriptive Statistics and Reliabilities of ICT Engagement Constructs*

	Singapore		Turkey		Overall	
	$\mu(SD)$	$\alpha$	$\mu(SD)$	$\alpha$	$\mu(SD)$	$\alpha$
IICT	3.14( 0.68)	.792	2.82( 0.44)	.860	2.98( 0.56)	.846
PICT	2.95( 0.80)	.806	2.80( 0.56)	.872	2.87( 0.68)	.846
PAICT	3.02( 0.47)	.867	2.72( 0.39)	.874	2.87( 0.43)	.876
SRICT	2.69( 0.06)	.850	2.72( 0.04)	.868	2.70( 0.05)	.859

Science Performance: Science literacy defined within the scope of PISA research is considered as the ability of students to deal with issues related to science and to reflect on scientific facts. Science literacy requires the ability to explain facts, design research methods, and interpret evaluation data and findings scientifically (OECD, 2019a). Science performance in PISA measures students' science literacy in the use of scientific knowledge to determine questions, gain new knowledge, describe scientific phenomena, and draw evidence-based conclusions about issues related to science. The science performances of 79 countries participating in PISA 2018 were evaluated over their average scores and results showed that the average science scores were varied between 59 and 336. Turkey, ranked 39 in science among 79 countries participating in PISA 2018, it ranked 30th among the 37 OECD countries (OECD, 2019d). Singapore was one of the top countries in science.

Measurement Invariance: Measurement invariance (MI) evaluates whether a construct is measured and interpreted in the same way across different groups and is a requirement for making valid comparisons (Putnick & Bornstein, 2016). CFA can be used within the scope of SEM to test measurement invariance. There are four hierarchical levels of MI in Multi-group CFA and each of these levels is based on the additional equality constraints on the model parameters if the previous invariance is met. Configural invariance, which is the first step of assessing measurement invariance, explores if the same items measure the same constructs across groups. Factor models belonging to all groups to be compared are estimated at the same time. Since this is the baseline model, the validity of the configural invariance is evaluated by the model fit measures. The configural model is a baseline model to compare with metric invariance (weak factorial invariance). After providing configural invariance, metric invariance is explored for whether factor loadings are equivalent across groups. Providing invariance of factor loadings shows that the construct has the same meaning across groups. After providing metric invariance, scalar invariance of item intercepts, is explored for metric invariant items. Scalar invariance (strong factorial invariance) indicates mean equivalence in different groups. After providing scalar invariance, the final step is to test residual invariance. The residual invariance (strict invariance) is required for full measurement invariance. The residual invariance is not required for testing mean differences. Since the residual invariance is insignificant for the interpretation of latent mean differences, this step can be skipped in many studies or if this step cannot be provided, latent factor means can be compared (Vandenberg & Lance, 2000).

#### *Data Analysis*

Mplus 6.1 and R Studio tools were used to analyze the data. First step, exploratory factor analysis (EFA) was applied to identify the structure of ICT engagement. After demonstrating the convergent validity and the discriminant validity, we used the Cronbach's alpha for assessing factor reliability.

Before investigating invariance, it is important to ensure that the ICT engagement model provides a good fit for both countries. Thus, the second step was to test whether the proposed four-factor ICT engagement construct fitted the data from each country using the single group CFA approach. In this step, the four-dimensional construct of ICT engagement was tried to confirm for both countries. The measurement models of ICT engagement were estimated via CFA using Maximum likelihood estimation (ML). Before conducting the CFA, the assumptions of



normality were explored. The skewness values of the items varied between (-.92; -.14) and the kurtosis values of items varied between (-.76; .94). If the absolute values of skewness and kurtosis are below 1 deviation from normality is defined as slight, between 1 and 2.3, moderate, and above 2.3, severe. (Lei & Lomax, 2005). The absolute values of ICT engagement items skewness and kurtosis were below 1 the deviation from normality was weak so ML estimation was used in this research (Ooi et al., 2012; Şimşek & Tekeli, 2015). To evaluate the measurement model fit, three most common fit indices (Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA) and Standardized RMR (SRMR)) were used. CFI values more than .90 and RMSEA and SRMR values smaller than .08 indicate an acceptable model fit, whereas CFI values more than .95 and RMSEA and SRMR values smaller than .05 suggest good model fit (Hu & Bentler, 1999; Marsh et al., 2005)

After the ICT engagement construct was provided for each country, in the third step MI was tested using the multistage procedure of Multi-Group CFA. A configural model tested for whether the proposed structure of ICT engagement would be equal across the two groups. The configural model included the same number of factors and the same number of items. There was not equality restriction on measurement and structural parameters across countries. The Singapore and Turkey model were estimated at the same time. After the configural invariance was provided, the factor coefficients were kept equal for both groups to test metric invariance. The Likelihood-Ratio Test (LR) was used to evaluate the model fit in the measurement invariance analysis (Cheung & Rensvold, 2009). The change in CFI ( $\Delta$ CFI) criterion which is less sensitive to the sample size and alternative fit indices ( $\Delta$ RMSEA,  $\Delta$ SRMR) were also considered. Chen (2007) suggested that such changes should be equal or less than .01 for the  $\Delta$ CFI, .015 for the  $\Delta$ RMSEA and .010 for the  $\Delta$ SRMR. Metric invariance held, then, the scalar invariance model was examined. Factor loadings and item intercepts were kept equal in both countries. The results showed that scalar invariance model fit was acceptable. Thus, both the factor loadings and the item intercepts of ICT engagement scale were invariant across Singapore and Turkey. After scalar invariance held, residual invariance was examined. The residual invariance was not supported based on the chi-square difference test. As a result, we demonstrated scalar invariance of the scale with 4 factors and 21 items across the two countries; thus, we could proceed to structural invariance. When we explored the structural invariance, we only tested the factor mean invariance using the method that was recommended by Vandenberg and Lance (2000). Singapore was taken as the reference group when comparing factor means, so the estimated factor means for countries were actually the differences in factor means between groups. We demonstrated strong factorial invariance including configural invariance, metric invariance, and scalar invariance of ICT engagement model across groups, so we were able to use ICT engagement to meaningful and valid comparisons.

For the comparison of the effects of ICT engagement factors on performance of science between these two countries, we used the Multi-group SEM analysis in the fourth step. Before comparing the path coefficients across the countries, each of the two groups were modeled separately (Jiang et al., 2021). After that, the configural SEM model was explored considering the two groups simultaneously without any equality constraint on the structural path coefficients.

## Research Results

### *Exploratory Factor Analysis (EFA)*

First, EFA was performed on a total of 21 items to determine the factors. Kaiser-Meyer-Olkin (KMO), the measure of sampling adequacy should be greater than .5, KMO value was .934 which indicated the suitability for factor analysis. Bartlett's test of sphericity was rejected ( $p < .001$ ). This demonstrated that there were appropriate correlations in the data for factor analysis. The EFA results using Principal Components Factoring with Promax rotation revealed four significant factors. The results showed that 63.50% of the total variance was explained by these four factors. Standardized factor loadings of 21 items are illustrated in Table 2.

As shown in Table 2, all the item loadings were perfect (Tabachnick & Fidell, 2007). All the items were loaded stronger on the related factors than on the other factors and there were no items with noticeable cross-loads. Thus, convergent validity and discriminant validity were demonstrated (Churchill, 1979). The internal consistency of the factors was evaluated with Cronbach's alpha and they were found to be above the recommended threshold value of .60 (Hair et al., 1998). So, the scale was found to be reliable.



**Table 2**  
*Standardized Factor Loadings and Cronbach's  $\alpha$* 

Factors	IICT	PICT	PAICT	SRICT
Standardized factor loadings	.658	.702	.831	.793
	.770	.811	.803	.820
	.787	.680	.778	.695
	.737	.864	.837	.862
	.728	.863	.831	.820
Cronbach's $\alpha$	.818	.846	.876	.859

*Single group CFA*

Table 3 shows the model fit indices of the overall data and each of the country for single group CFA. The results showed an acceptable fit for Singapore and the overall data. All the CFI values were greater than .90, all the RMSEA and SRMR were less than .08. For Turkey, the results showed a good fit. The CFA was .947 and the RMSEA and SRMR were less than .05. All the results showed that the four factor of ICT engagement scale was supported in both countries.

**Table 3**  
*Model Fit Indices of the CFA*

	$\chi^2(df)$	RMSEA (90%-CI)	CFI	SRMR
Overall	15103.396 (400)	.075 (.074-.076)	.912	.079
Singapore	6967.367 (183)	.076 (.075-.078)	.911	.063
Turkey	4081.186 (183)	.057 (.056-.059)	.947	.034

*Multi-group CFA*

Table 4 represents the results of the Multi-group CFA. As shown in Table 4, configural model provided acceptable fit for the data (CFI=.92>.90, RMSEA=.053<.08 and SRMR=.062<.10) which indicated the construct equivalence of the ICT engagement across Singapore and Turkey. The metric model fit was found to be acceptable (CFI=.92>.90, RMSEA=.053<.08 and SRMR=.061<.10) and metric invariance was supported based on the chi-square difference test ( $c^2_{diff}=2682.127$ ,  $\Delta df=17$ ,  $p>.001$ ). In addition,  $\Delta CFI \leq .01$ ,  $\Delta RMSEA \leq .015$ , and  $\Delta SRMR \leq .010$  (Chen, 2007). So, the metric invariance indicated that the items were equivalently related to the latent factors. Furthermore, the scalar invariance model fit was found to be acceptable (CFI=.92>.90 RMSEA=.053<.08 and SRMR=.061<.10). We also conducted LR test with the current model ( $\Delta \chi^2 = 16.840$ ;  $df = 18$ ;  $p = .5341$ )  $c^2_{diff} = 1372.716$ ,  $\Delta df=17$ ,  $p>.001$ )  $\Delta \chi^2 = 10.273$ ;  $df = 18$ ;  $p = .9226$ ). and  $\Delta CFI$ ,  $\Delta RMSEA$  and  $\Delta SRMR$  indicated that scalar invariance was held. After scalar invariance provided, residual invariance was examined. The tests of differences in fit between residual invariance model and scalar model ( $c^2_{diff}=3\Delta \chi^2 = 194,690$ ;  $\Delta df= 21$ ,  $p<.001$ );  $df = 22$ ;  $p = .000$ ) indicated that residual invariance was not established.



**Table 4***Fit Indices for Invariance Tests of Measurement Model*

Model	CFI	RMSEA	SRMR	$\Delta\chi^2(\Delta df)$	$\Delta CFI$	$\Delta RMSEA$	$\Delta SRMR$
Configural Model	.91	.075	.079	-	-	-	-
Metric Model	.91	.070	.068	2682.127(17)	.00	-.005	-.011
Scalar Model	.92	.067	.051	1372.716 (17)	-.01	-.003	-.008
Residual Model	.90	.062	.071	3194.690 (21)	-.02	.000	.020

Even if residual invariance cannot be achieved, groups can still be compared on the latent variable; strong factorial invariance is sufficient to make valid comparisons. Singapore was considered the reference group where all factor means were constrained to equal 0. Actually, estimated factor means were differences in factor means between Turkey and Singapore. The factor means invariance demonstrated that the factor means of interest in ICT ( $-.293, p < .001$ ), perceived ICT competence ( $-.096, p < .001$ ) and perceived autonomy in using ICT ( $-.326, p < .001$ ) were significantly lower in Turkey than in Singapore while the factor mean ( $.042, p < .001$ ) of social relatedness in using ICT was significantly higher in Turkey than in Singapore.

#### *Multi-group SEM*

We used Multi-group SEM to explore the equality or invariance of the path coefficients across the two countries. Before comparing the path coefficients across the countries, each of the two groups were modeled separately. The Singapore model was acceptable (RMSEA=.075, 90% CI=(.074, .077); SRMR=.064; CFI=.900). Interest in ICT (.178,  $p < .001$ ) and perceived autonomy in using ICT (.208,  $p < .001$ ) had positive effect on science performance. Perceived ICT competence ( $-.055, p < .01$ ) and social interaction using ICT ( $-.305, p < .001$ ) had negative effect on science performance. The Turkey model also was acceptable (RMSEA=.06, 90% CI= (.059, .062); SRMR=.037; CFI=.937). In the Turkey model, interest in ICT (.205,  $p < .001$ ), perceived ICT competence (.185,  $p < .001$ ) and perceived autonomy in using ICT (.063,  $p < .01$ ) had significant positive effect on science performance. Social relatedness in using ICT ( $-.209, p < .001$ ) had negative effect on science performance. Singapore and Turkey baseline SEM model fitted data very well.

To test the invariance of path coefficients, we estimated a configural SEM model for both Singapore and Turkey at the same time. The SEM model of the two groups, which was defined as a baseline model, showed an acceptable fit for the data (RMSEA=.062, 90% CI=(.061, .063); SRMR=.067; CFI=.900).

As the Multi-group SEM was supported, the direct effect of interest in ICT on science performance was restricted to be equal across the groups. The Wald test ( $c^2=14.654; df=1; p < .001$ ) showed that the direct effect of interest in ICT on science performance was different for Singapore and Turkey. The direct effect of interest in ICT on science performance was lower in Singapore (.125,  $p < .001$ ) than in Turkey (.248,  $p < .001$ ). After that, the direct effect of perceived ICT competence on science performance was constrained to be equal across countries. Wald test ( $c^2=37.938; df=1; p < .001$ ) indicated that the direct effect of perceived ICT competence on science performance was non invariant for Singapore and Turkey. The direct effect of Perceived ICT competence on science performance was lower in Singapore (.055,  $p < .001$ ) than in Turkey (.092,  $p < .001$ ). Later, the direct effect of perceived autonomy in using ICT on science performance was constrained to be equal across the groups. Wald test ( $c^2=51.826; df=1; p < .001$ ) showed that the direct effect of perceived autonomy in using ICT on science performance was non invariant for Singapore and Turkey. The direct effect of perceived autonomy in using ICT on science performance was lower in Singapore (.088,  $p < .001$ ) than in Turkey (.151,  $p < .001$ ). After that, the direct effect of social relatedness in using ICT on science performance was set to equal across groups. Wald test ( $c^2=63.334; df=1; p < .001$ ) showed that the direct effect of social relatedness in using ICT on science performance was non invariant for Singapore and Turkey. The direct effect of social relatedness in using ICT on science performance was lower in Singapore ( $-.215, p < .001$ ) than in Turkey ( $-.312, p < .001$ ).



## Discussion

The aim of this research was to explore the effects of ICT engagement factors on science performance across Singapore and Turkey. The first step was to explore the measurement invariance of the ICT engagement scale across these two countries. The single group CFA results confirmed the four-dimensional structure of the ICT engagement scale. All items were loaded on the related factors of ICT engagement and all factors were reliable. The multi-group CFA results demonstrated that ICT engagement scale with 4 factors and 21 items had strong factorial invariance (configural, metric and scalar invariance) across these two countries. The ICT engagement had the same construct across Singapore and Turkey, so we were able to use ICT engagement to meaningful and valid comparisons. After the strong factorial invariance was confirmed, we tested factor mean invariance by treating Singapore as the reference group. The factor means invariance model showed that the factor means of interest in ICT, perceived ICT competence and perceived autonomy in using ICT were significantly lower in Turkey than in Singapore while the factor mean of social relatedness in using ICT was significantly higher in Turkey than in Singapore. According to the International Telecommunication Union (ITU) 2017 report, Singapore with a score of 8.05 had a higher ICT performance compared to Turkey with a score of 6.08. Singapore was at the top of this ranking, while Turkey was in the middle. Our results were parallel to levels of ICT development for these two countries except social relatedness in using ICT.

The multi group SEM results demonstrated that interest in ICT, perceived ICT competence and perceived autonomy in using ICT had positive direct effect on science performance and these effects were lower in Singapore than in Turkey. The social relatedness in using ICT had negative direct effect on science performance both in Singapore and in Turkey; this effect was lower in Singapore than in Turkey. The positive and significant effects of interest in ICT, perceived ICT competence and perceived autonomy in using ICT indicated that both Singapore and Turkey considered the role of ICT in education in a similar manner. These results were consistent for both countries, and they were compatible with the ICT policies. The negative effects of social relatedness on science performance emerged from the possible adverse side effect of ICT. These results were consistent with literature as expected. The higher effect for Turkey might be due to the fact that the students use ICT for social purposes rather than learning.

Students' interest in ICT showed significant positive effect on science performance both in Singapore and in Turkey. This result was also supported by previous studies showing that interest in ICT had a positive relationship with students' academic performance (Hu et al., 2018; Jansen et al., 2016; Lee & Wu, 2012; Meng et al., 2019; Xiao & Hu, 2019). Some of the studies showed that interest in ICT did not have significant effect on academic performance (Juhaňák et al., 2019), but most of these studies only analyzed a specific country. Students' interest in ICT was related to the pleasure and positive feelings of using products based to ICT such as mobile devices or computers (Zylka et al., 2015). According to the results of this research and other literature, students who are more interested in ICT use are likely to have better science learning outcomes. This can be explained as students who are more interested in ICT will participate in learning activities using computers or the internet more often than other students (Jansen et al., 2016; Lee & Wu, 2012). Also, these students will have a more motivated and positive attitude towards science learning with technology (Park & Weng, 2020). Students interested in ICT can learn science with an interactive educational software, training software or computer tutorial that are designed to help student learning. Students interested in ICT learn when and how they can use different tools and teachers can also inform students to use the right tools. For example, word processing software helps students for organizing ideas, writing homework and projects the works. Students can use spreadsheet for analyzing and modeling scientific data.

Students' perceived ICT competence also showed a significant positive effect on students' science performance both Singapore and Turkey. This result supported other studies' results (Hosein et al., 2010; Hu et al., 2018; Selwyn & Husen, 2010). Students with high perceived ICT competence can motivate themselves to solve more difficult issues with more effective strategies. According to these findings, students with high perceived ICT competence were more likely to use software or online resources to work than those with low ICT competencies (Hosein et al., 2010). However, some studies supported that ICT competence had no effect or it had negative relationship with performance (Juhaňák et al.2016; Xiao & Hu, 2019). The results varied depending on students' grade levels and which country was analyzed (Park & Weng, 2020). The competence in using ICT is considered an important skill that students need to acquire in order to be successful in the digital age.



Students' perceived ICT autonomy had a significant positive effect on students' science performance both in Singapore and in Turkey. This result was consistent with the literature (Cárdenas-Claros & Oyanedel, 2016; Xiao & Hu, 2019; Meng et al., 2019). Autonomy implies that students can organize their learning and use ICT to complete tasks and achieve mastery (Fu, 2013). Students with higher autonomy in the use of ICT tend to take more control of their learning processes with technology. Moreover, when students realize that they can control their learning with ICT, they can strengthen their autonomy in using ICT and learn more by using ICT effectively (Serhan, 2009; Park & Weng, 2020). Considering the positive relationship between perceived ICT autonomy and students' science performance, it becomes necessary to organize the education system to support autonomy. Both parents and teachers can provide support to meet the autonomy needs of students. Teachers can direct students to science group work where they will use tools related to ICT and make them aware of their own achievements and shortcomings (Park & Weng, 2020).

Social relatedness in using ICT was significantly a negative effect on science performance both in Singapore and in Turkey, and its effect size was larger than ICT interest, competence, and autonomy. These obtained results were similar to some previous studies (Paul et al., 2012; Huang, 2018; Hu et al., 2018). For example, Hu et al. (2018) reported that students who used ICT for higher social interaction performed lower. Students who use social media too much have less time to learn (Englander et al., 2010). While using ICT for learning purposes, students may also lose their focus as they interact with other ICT-related activities such as games, chats, and social media alerts. Parents and teachers should alert students to the addiction of entertainment as well as motivate them to use ICT for learning purposes (Park & Weng, 2020).

## Conclusions and Implications

In this research the relationship between ICT engagement factors and science performance was explored by Multi-group SEM across Turkey and Singapore based on the data for PISA 2018. These countries were selected for comparison purpose because they intended to use ICT in education indicated in their national plans. The success of Singapore in science performance was evident. So, it was the reference for comparison to the Turkey which gained fair improvement in recent PISA cycles. As a preliminary requirement of Multi-group SEM, the measurement invariance of ICT scale across these countries was provided hierarchically validating configural, metric, and scalar invariance. The Multi-group SEM result indicated that interest, perceived competence, and autonomy in ICT use showed a positive effect while social relatedness in using ICT had a negative effect on students' science performance both Singapore and Turkey. Although these effects were not different in their directions, their magnitudes were higher in Turkey than in Singapore.

This research contributes to the field of education both because it shows that the ICT engagement construct is comparable and because it shows the effect of four factors of ICT on science performance separately between these two countries. The results of this research can be a guide in educational policies to be determined to increase science performance and it will also be useful in positioning ICT in education system.

The positive effects of interest, perceived competence, and autonomy in ICT use on science performance can be regarded as an opportunity to the developing countries like Turkey considering the benefits of ICT in education. Turkey was in the middle rank of science performance according to PISA 2018 results, and it might be starting to appear in the positive results of these ICT policies implemented. The negative effect of social relatedness in using ICT on science performance should be handled by policy makers.

This research has a few limitations. First, the responses of students from Singapore and Turkey were analyzed. The results of this paper are limited to these selected countries. The research can be extended to different countries with different cultures and different educational structures. Second, the relationship between ICT engagement factors and science performance was explored. For future studies, the effect of ICT engagement factors on reading and mathematics performance can be explored. Third, in this research, only the comparison was made according to the countries, and no comparison was made by gender. It is planned to explore the measurement invariance of the ICT engagement scale according to gender.

## Declaration of Interest

Authors declare no competing interest.



## References

- Agasisti, T., Gil-Izquierdo, M., & Han, S. W. (2020). ICT Use at home for school-related tasks: What is the effect on a student's achievement? Empirical evidence from OECD PISA data. *Education Economics*, 28(6), 601–62. <https://doi.org/10.1080/09645292.2020.1822787>
- Cárdenas-Claros, M., & Oyanedel, M. (2015). Teachers' implicit theories and use of ICTs in the language classroom. *Technology, Pedagogy and Education*, 25(2), 207–225. <https://doi.org/10.1080/1475939X.2014.988745>
- Cheema, J., & Zhang, B. (2013). Quantity and quality of computer use and academic achievement: Evidence from a large-scale international test program. *International Journal of Education and Development using ICT*, 9(2), 95–106. <https://www.learntechlib.org/p/130285/>
- Chen, C. J., & Wang, H. (2013). The effectiveness of blended learning and e-learning on student learning outcomes: A meta-analysis of 47 experimental and quasi-experimental studies. *Open Education Research*, 19(2), 69–78.
- Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, 14(3), 464–504. <https://doi.org/10.1080/10705510701301834>
- Cheung, G. W., & Rensvold, R. B. (2009). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, 9(2), 233–255. [https://doi.org/10.1207/S15328007SEM0902\\_5](https://doi.org/10.1207/S15328007SEM0902_5)
- Churchill, G. A. (1979). A paradigm for developing better measures of marketing constructs. *Journal of Marketing Research*, 16(1), 64–73. <https://doi.org/10.1177/002224377901600110>
- Davidov, E., Meuleman, B., Cieciuch, J., Schmidt, P., & Billiet, J. (2014). Measurement equivalence in cross-national research. *Annual Review of Sociology*, 40(1), 55–75. <https://doi.org/10.1146/annurev-soc-071913-043137>
- De Wit, K., Heerwegh, D., & Verhoeven, J. C. (2012). Do ICT competences support educational attainment at university? *Journal of Information Technology Education: Research*, 11(1), 1–25. <https://www.learntechlib.org/p/111490/>
- Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, 11(4), 227–268. [https://doi.org/10.1207/s15327965pli1104\\_01](https://doi.org/10.1207/s15327965pli1104_01)
- Demkanin, P., Kibble, B., Lavonen, J., Guitart Mas, J., & Turlo, J. (Eds.) (2008). *Effective use of ICT in science education: [EU-ISE: (226382 - CP - 1 - 2005 - SK - COMENIUS - C21)]*. University of Edinburgh.
- Eickelmann, B., Gerick, J., & Koop, C. (2016). ICT use in mathematics lessons and the mathematics achievement of secondary school students by international comparison: Which role do school level factors play? *Education and Information Technologies*, 22(4), 1527–1551. <https://doi.org/10.1007/s10639-016-9498-5>
- Englander, F., Terregrossa, R. A., & Wang, Z. (2010). Internet use among college students: Tool or toy? *Educational Review*, 62(1), 85–96. <https://doi.org/10.1080/00131910903519793>
- Fu, J. (2013). Complexity of ICT in education: A critical literature review and its implications. *International Journal of Education and Development using ICT*, 9(1), 112–125. <https://files.eric.ed.gov/fulltext/EJ1182651.pdf>
- Goldhammer F., Gniewosz G., & Zylka J. (2016). ICT engagement in learning environments. In Kuger S., Klieme E., Jude N., & Kaplan D. (Eds.), *Assessing contexts of learning. methodology of educational measurement and assessment*. (pp. 331–93). Springer. [https://doi.org/10.1007/978-3-319-45357-6\\_13](https://doi.org/10.1007/978-3-319-45357-6_13)
- Hair, J. F., Black, W. C., Anderson, R. E., & Tatham, R. L. (1998). *Multivariate data analysis*. Englewood Cliffs.
- Hoseini, A., Ramanau, R., & Jones, C. (2010). Learning and living technologies: A longitudinal study of first-year students' frequency and competence in the use of ICT. *Learning, Media and Technology*, 35(4), 403–418. <https://doi.org/10.1080/17439884.2010.529913>
- Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, 6(1), 1–55. <https://doi.org/10.1080/10705519909540118>
- Hu, X., Gong, Y., Lai, C., & Leung, F. K. S. (2018). The relationship between ICT and student literacy in mathematics, reading, and science across 44 countries: A multilevel analysis. *Computers & Education*, 125, 1–13. <https://doi.org/10.1016/j.compedu.2018.05.021>
- Huang, C. (2018). Social network site use and academic achievement: A meta-analysis. *Computers & Education*, 119, 76–83. <https://doi.org/10.1016/j.compedu.2017.12.010>
- Jansen, M., Lüdtke, O., & Schroeders, U. (2016). Evidence for a positive relation between interest and achievement: Examining between-person and within-person variation in five domains. *Contemporary Educational Psychology*, 46, 116–127. <https://doi.org/10.1016/j.cedpsych.2016.05.004>
- Janneck, M., Vincent-Höper, S., & Ehrhardt, J. (2013). The computer-related self-concept: a gender-sensitive study. *International Journal of Social and Organizational Dynamics in IT (IJSODIT)*, 3(3), 1–16. <https://doi.org/10.4018/ijisodit.2013070101>
- Jiang, T., & Chen, J. G. (2021). Impact of instruction on science performance: Learning initiative as a mediator and gender as a limited moderator. *Journal of Baltic Science Education*, 20(1), 50–66. <https://doi.org/10.33225/jbse/21.20.50>
- Juhaňák, L., Zounek, J. Ř., Záleská, K., Bárta, O. Ř., & Vlčková, K. (2019). The relationship between the age at first computer use and students' perceived competence and autonomy in ICT usage: A mediation analysis. *Computers & Education*, 141, 103614. <https://doi.org/10.1016/j.compedu.2019.103614>
- Kilic Depren, S. (2020). Determination of the factors affecting students' science achievement level in Turkey and Singapore: An application of quantile regression mixture model. *Journal of Baltic Science Education*, 19(2), 247. <https://doi.org/10.33225/jbse/20.19.247>
- Kuger S., Jude N., Klieme E., Kaplan D. (2016). An introduction to the PISA 2015 questionnaire field trial: study design and analysis procedures. In Kuger S., Klieme E., Jude N., Kaplan D. (Eds.), *Assessing Contexts of Learning. Methodology of Educational Measurement and Assessment*. Springer. [https://doi.org/10.1007/978-3-319-45357-6\\_4](https://doi.org/10.1007/978-3-319-45357-6_4)



- Kunina-Habenicht, O., & Goldhammer, F. (2020). ICT Engagement: A new construct and its assessment in PISA 2015. *Large-Scale Assessments in Education*, 8(1), 1–21. <https://doi.org/10.1186/s40536-020-00084-z>
- Lee, Y.-H., & Wu, J.-Y. (2012). The effect of individual differences in the inner and outer states of ICT on engagement in online reading activities and PISA 2009 reading literacy: Exploring the relationship between the old and new reading literacy. *Learning and Individual Differences*, 22(3), 336–342. <https://doi.org/10.1016/j.lindif.2012.01.007>
- Lei, J., & Zhao, Y. (2007). Technology uses and student achievement: A longitudinal study. *Computers & Education*, 49(2), 284–296. <https://doi.org/10.1016/j.compedu.2005.06.013>
- Lei, M., & Lomax, R. G. (2005). The effect of varying degrees of nonnormality in structural equation modeling. *Structural Equation Modeling: A Multidisciplinary Journal*, 12(1), 1–27. [https://doi.org/10.1207/s15328007sem1201\\_1](https://doi.org/10.1207/s15328007sem1201_1)
- Liem, G. A. D., Martin, A. J., Anderson, M., Gibson, R., & Sudmalis, D. (2014). The role of arts-related information and communication technology use in problem solving and achievement: Findings from the programme for international student assessment. *Journal of Educational Psychology*, 106(2), 348–363. <https://doi.org/10.1037/a0034398>
- Luu, K., & Freeman, J. G. (2011). An analysis of the relationship between information and communication technology (ICT) and scientific literacy in Canada and Australia. *Computers & Education*, 56(4), 1072–1082. <https://doi.org/10.1016/j.compedu.2010.11.008>
- Ma, Y., & Qin, X. (2021). Measurement invariance of information, communication and technology (ICT) engagement and its relationship with student academic literacy: Evidence from PISA 2018. *Studies in Educational Evaluation*, 68, 100982. <https://doi.org/10.1016/j.stueduc.2021.100982>
- Marsh, H. W., Hau, K.-T., & Grayson, D. (2005). *Goodness of fit in structural equation models*. In A. Maydeu-Olivares & J. J. McArdle (Eds.), *Multivariate applications book series. Contemporary psychometrics: A festschrift for Roderick P. McDonald* (p. 275–340). Lawrence Erlbaum Associates Publishers. <https://psycnet.apa.org/record/2005-04585-010>
- Mătă, L., Lazăr, I. M., & Ghițău, R. (2020). Exploring academic dishonesty practices among science education university students. *Journal of Baltic Science Education*, 19(1), 91–107. <https://doi.org/10.33225/jbse/20.19.91>
- Meng, L., Qiu, C., & Boyd-Wilson, B. (2019). Measurement invariance of the ICT engagement construct and its association with students' performance in China and Germany: Evidence from PISA 2015 data. *British Journal of Educational Technology*, 50(6), 3233–3251. <https://doi.org/10.1111/bjet.12729>
- Notten, N., & Kraaykamp, G. (2009). Home media and science performance: A cross-national study. *Educational Research and Evaluation*, 15(4), 367–384. <https://doi.org/10.1080/13803610903087045>
- OECD. (2019a). *PISA 2018 assessment and analytical framework*. Paris: PISA, OECD Publishing. <https://doi.org/10.1787/b25efab8-en>
- OECD. (2019b). *PISA 2018 technical report*. OECD Publishing. <https://www.oecd.org/pisa/data/pisa2018technicalreport/>
- OECD. (2019c). Country note, Results from PISA 2018. OECD Publishing. [https://www.oecd.org/pisa/publications/PISA2018\\_CN\\_SGP.pdf](https://www.oecd.org/pisa/publications/PISA2018_CN_SGP.pdf)
- OECD. (2019d). Country note, Results from PISA 2018. OECD Publishing. [https://www.oecd.org/pisa/publications/PISA2018\\_CN\\_TUR.pdf](https://www.oecd.org/pisa/publications/PISA2018_CN_TUR.pdf)
- Ooi, K.B., (2015). TQM practices and knowledge management: A multi-group analysis of constructs and structural invariance between the manufacturing and service sectors. *Total Quality Management & Business Excellence*, 26(11-12), 1131–1145. <https://doi.org/10.1080/14783363.2014.914642>
- Park, S., & Weng, W. (2020). The relationship between ICT-related factors and student academic achievement and the moderating effect of country economic index across 39 countries: Using multilevel structural equation modelling. *Educational Technology & Society*, 23(3), 1-15. <https://www.jstor.org/stable/pdf/26926422.pdf?refreqid=excelsior%3A821cc1fea6a861ce20fa1e353e18c4ed>
- Paul, J. A., Baker, H. M., & Cochran, J. D. (2012). Effect of online social networking on student academic performance. *Computers in Human Behavior*, 28(6), 2117–2127. <https://doi.org/10.1016/j.chb.2012.06.016>
- Putnick, D. L., & Bornstein, M. H. (2016). Measurement invariance conventions and reporting: The state of the art and future directions for psychological research. *Developmental Review*, 41, 71–9. <https://doi.org/10.1016/j.dr.2016.06.004>
- Selwyn, N., & Husen, O. (2010). The educational benefits of technological competence: An investigation of students' perceptions. *Evaluation & Research in Education*, 23(2), 137–141. <https://doi.org/10.1080/09500790.2010.483515>
- Senkbeil, M., & Ihme, J. M. (2017). Motivational factors predicting ICT literacy: First evidence on the structure of an ICT motivation inventory. *Computers & Education*, 108, 145–158. <https://doi.org/10.1016/j.compedu.2017.02.003>
- Serhan, D. (2009). Preparing pre-service teachers for computer technology integration. *International Journal of Instructional Media*, 36(4), 439–448. [https://www.jstor.org/stable/26926422?seq=1#metadata\\_info\\_tab\\_contents](https://www.jstor.org/stable/26926422?seq=1#metadata_info_tab_contents)
- Şimşek, G. G., & Tekeli, F. N. (2015). Understanding the antecedents of customer loyalty by applying structural equation modeling. In U. Akküçük (Ed.), *Handbook of Research on Developing Sustainable Value in Economics, Finance, and Marketing* (pp. 420–445). IGI Global. <https://doi.org/10.4018/978-1-4666-6635-1.ch025>
- Tabachnick, B. G., & Fidell, L. S. (2007). *Experimental designs using ANOVA*. Thomson/Brooks/Cole.
- Thiessen, V., & Dianne Looker, E. (2007). Digital divides and capital conversion: The optimal use of information and communication technology for youth reading achievement. *Information, Communication & Society*, 10(2), 159–18. <https://doi.org/10.1080/13691180701307370>
- Vandenberg, R. J., & Lance, C. E. (2000). A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational Research Methods*, 3(1), 4–7. <https://doi.org/10.1177/109442810031002>



- Xiao, Y., & Hu, J. (2019). Assessment of optimal pedagogical factors for Canadian ESL learners' reading literacy through artificial intelligence algorithms. *International Journal of English Linguistics*, 9(4), 1. <https://doi.org/10.5539/ijel.v9n4p1>
- Xin, T., & Zhou, D. (2010). The impact of computer use in class on junior high school students' math achievement. *Journal of Educational Studies*, 6(4), 65–7. [https://en.cnki.com.cn/Article\\_en/CJFDTotal-XKJY201004014.htm](https://en.cnki.com.cn/Article_en/CJFDTotal-XKJY201004014.htm)
- Zylka, J., Christoph, G., Kroehne, U., Hartig, J., & Goldhammer, F. (2015). Moving beyond cognitive elements of ICT literacy: First evidence on the structure of ICT engagement. *Computers in Human Behavior*, 53, 149–16. <https://doi.org/10.1016/j.chb.2015.07.008>

Received: March 12, 2021

Accepted: July 20, 2021

Cite as: Özkan, B., & Noyan Tekeli, F. (2021). The effects of information and communication technology engagement factors on science performance between Singapore and Turkey using multi-group structural equation modeling. *Journal of Baltic Science Education*, 20(4), 639-650. <https://doi.org/10.33225/jbse/21.20.639>

**Batuhan Özkan**

PhD, Research Assistant, Department of Statistics, Faculty of Arts and Science, Yildiz Technical University, Davutpasa Campus, Istanbul, 34220, Turkey.  
E-mail: [baozkan@yildiz.edu.tr](mailto:baozkan@yildiz.edu.tr)  
Website: <https://avesis.yildiz.edu.tr/baозkan>  
ORCID: <https://orcid.org/0000-0002-1773-9317>

**Fatma Noyan Tekeli**  
(Corresponding author)

PhD, Professor, Department of Statistics, Faculty of Arts and Science, Yildiz Technical University, Davutpasa Campus, Istanbul, 34220, Turkey.  
E-mail: [fnoyan@yildiz.edu.tr](mailto:fnoyan@yildiz.edu.tr)  
Website: <https://avesis.yildiz.edu.tr/fnoyan>  
ORCID: <https://orcid.org/0000-0002-1095-249X>

