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The Effect of Self-Confidence on Mathematics Achievement: The Meta-Analysis of Trends in International Mathematics and Science Study (TIMSS)

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The aim of this study is to examine the effect of self-confidence on mathematics achievement. In this meta-analysis, the effect of self-confidence on mathematics achievement was analysed using the Trends in International Mathematics and Science Study (TIMSS). In the first stage of the study, the average effect size of self-confidence on mathematics achievement was determined, and in the second stage, the moderators that may impact average effect size were investigated. For the meta-analysis, 336 independent data belonging to 76 countries included in the TIMSS (2003, 2007, 2011 and 2015) were combined, and a sample of 1,028,567 subjects was obtained. The average effect size was then calculated using the differences between means (Cohen d) based on the random effect model, whereas the significance of the moderator variables was calculated using the Q statistic. The results indicated that self-confidence has a moderate effect on mathematics achievement. In addition, the year in which the survey was conducted, national culture, continent of the country and Human Development Index were found to play a moderator role in the effect of self-confidence on mathematics achievement. In this respect, the economic, cultural and social capital of students are very similar to each other as the economic levels of the countries and individual families increase. These similarities highlight the differences between students' personal characteristics, wherein traits such as self-confidence have become one of the most important variables that determine students' mathematics achievement in recent years.

Keywords: self-confidence, mathematics achievement, meta-analysis, country culture, human development index

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INTRODUCTION

Self-confidence is one of the most important psychological structures and is the subject of much of the existing research on students' mathematics achievement (Hammouri, 2004; Hosein & Harle, 2018; Kadijevich, 2018; Kvedere, 2014; Waini, et al., 2014). One of the key concepts first applied in Social Cognitive Theory (Bandura, 1977), it has also been conceptualized in some sources as 'self-efficacy'. However, while these two terms are often used interchangeably, they in fact represent similar but not identical concepts. In this sense, self-efficacy refers to 'individuals' self-beliefs about their capacity to generate defined behaviors on the events that will affect their lives' (Bandura, 1994). Zimmerman (2000) likewise describes self-efficacy as 'an individual's judgement about his/her ability to perform and achieve a job'. On the other hand, self-confidence refers more broadly to an individual's belief in him/herself. Thus, looking at both definitions, it can be understood that self-efficacy is a belief that is specific to a particular situation, while self-confidence is a general personality trait. Accordingly, self-efficacy can be conceptualized as case-specific self-confidence. For example, a student's belief in his or her ability to fulfill the behaviors required to complete a task for the mathematics lesson indicates self-efficacy, whereas his or her beliefs in his overall ability with respect to mathematics learning indicates self-confidence. Both of these concepts are recognized in the literature as psychological structures that play an important role in the achievement of a desired objective.

In relation to self-efficacy, self-confidence is an important determinant of an individual's feelings, thoughts, behaviors and motivation for a task (Bandura, 1977). For example, individuals with low self-confidence may avoid difficult tasks, perceiving them as threats and giving up quickly when they encounter difficulties; while individuals with high self-confidence typically make greater efforts to complete a task and are more persistent in the face of challenges (Bandura, 1994; Bandura, 1977; Feldman & Kubota, 2015; Honicke & Broadbent, 2016; Hosein & Harle, 2018; Pajares & Miller, 1994). In this respect, the beliefs of individual have an effect on their performance. Moreover, when individuals are successful in a given instance, their positive beliefs increase, while making repeated errors increases negative beliefs (Bandura, 1982). Therefore, research has shown that individuals with high levels of self-confidence tend to succeed academically (Egorova & Chertkova, 2016; Feldman & Kubota, 2015; Honicke & Broadbent, 2016; Kukulu, et al., 2013; Lent, et al., 1997; Miscevic-Kadijevic, 2015; Morony, et al., 2013; Stankov, 2014; Pajares & Graham, 1999; Pajares & Miller, 1994; York, Gibson & Rankin, 2015). From this perspective, self-confidence is one of the most important psychological structures that should be emphasized in the educational process.

With respect to mathematics education, in particular, research has shown that students' self-confidence in mathematics skills and in the learning, process is an important predictor of mathematics achievement, as the success or failure of the students in mathematics courses is generally in line with their level of self-confidence in mathematics. Accordingly, it is recognized that students who are successful in mathematics have higher self-confidence than other students (Hackett, 1985; Hackett &

Betz, 1989; Honicke & Broadbent, 2016; Hosein & Harle, 2018; Pajares & Miller, 1994). In addition, high self-confidence in mathematics course reduces math anxiety, another factor that increases mathematics achievement (Feldman & Kubota, 2015; Klassen, 2004; Kvedere, 2014; Phan & Walker, 2000).

In international studies such as PIRLS, PISA, and TIMSS, where students' mathematical knowledge and skills are evaluated in a multilateral way, self-confidence in mathematics has been investigated as an important dimension in mathematics achievement. The International Mathematics and Science Trends Survey, or TIMSS, is a conducted by the International Association for the Evaluation of Educational Achievement (IEA) at four-year intervals. TIMSS evaluates the knowledge and skills of 4th- and 8th-grade students with respect to mathematics and science. In addition to evaluating students' achievements on a specific scale, the research was also designed to determine how learning and teaching in mathematics and science are carried out in schools and to measure and evaluate the differences between national education systems around the world. In this context, mathematics and science achievement tests, and student, teacher and school surveys are used in TIMMS (Büyüköztürk, Çakan, Tan & Atar, 2014; Şişman, Acat, Aypay & Karadağ, 2011). The related mathematics achievement test contains questions in the learning areas of numbers, algebra, geometry, data and probability, and there are items relating to the cognitive processes of knowledge, implementation and reasoning for each learning area. In TIMSS mathematics student surveys, the relationship between mathematics achievement and students' attitudes, values and self-confidence are investigated.

Within the scope of TIMSS, the 'Students' Self-Confidence Index in Learning Mathematics' was developed, wherein students' self-confidence in mathematics/learning mathematics was investigated as a sub-dimension. This index was determined through questions such as "I'm usually good at math courses," "mathematics is harder for me compared to most of my classmates," "I only fail in mathematics," "I learn math topics quickly," "I'm good at solving difficult math problems," and "for me mathematics is more difficult than other fields (TIMSS Report, 2007, 2011).

The research that has been conducted to reveal the effect of self-confidence on academic achievement, and in particular on mathematics achievement, has mainly been limited to data obtained from small samples and non-standardized achievement tests. This study, departing from this limitation, aimed to analyze the results of TIMSS, in which standardized achievement tests were used. In doing so, the research was carried out in two stages. In the first stage, the effect of self-confidence on mathematics achievement was determined; and in the second stage, the moderators that might impact average effect size were investigated. For this purpose, the following hypotheses were tested:

H_1 Self-confidence affects students' mathematics achievement.

H_2 School level, year of the survey, national culture[1], continent where a country is located and the Human Development Index[2] are moderators regarding the effect of self-confidence on mathematics achievement.

METHOD

Sample of Study and Selection Criteria

Although there are many individual studies that have investigated the effect of self-confidence on mathematics achievement, there are few comparative studies based on standardized achievement tests. This study aims to overcome this deficiency through a meta-analysis of the TIMSS results, in which standardized achievement tests were used. For this purpose, the results of 336 independent studies from 76 countries in four TIMSS (2003, 2007, 2011 and 2015) were combined, creating a sample group of 1,028,567 subjects.

Coding Process

Coding is the process of extracting data from individual studies for the purpose of obtaining suitable data suitable for analysis (Çoğaltay & Karadağ, 2015). In this study, a coding form comprising the following components was generated prior to performing the statistical analysis:

- Sample information [Year of study, country, course, etc.]
- Quantitative figures [Sample size, average achievement, standard deviation, etc.]

Effect Size Analysis

Average effect size is a standard measure used in meta-analysis to determine the strength and direction of a relationship (Borenstein, Hedges, Higgins, & Rothstein, 2009). In this study, the *Standardized Means Differences* (Cohen *d*) were calculated for the analysis of the hypothesis; while Standardized Average Effect Size was used to compare the means of independent groups, which is considered to be comparable for studies based on each of the two variables (Hedges & Olkin, 1985). The meta-analysis process of this study was based on the *random effects model*, and the *Comprehensive Meta-Analysis* program was used to analyze the data.

Moderator Variables and Moderator Analysis

Moderator analysis is a procedure that tests the direction of differences between sub-groups and between the average effect sizes of variables (moderators). The statistical significance of the difference between the moderator variables is tested by the Q-

[1] Culture is collective mind programming that distinguishes the members of one group or category from others (Hofstede, 2001). In this context, Triandis (1995) has theorized various national culture forms, such as horizontal-individualism and vertical-collectivism.

[2] The Human Development Index (HDI) is a statistic composite index of life expectancy, education, and per capita income indicators, which are used to rank countries into four tiers of human development (UNDP, 2018).

statistics method developed by Hedges and Olkin (1985). In this study, only Q_b values were used, since the statistical significance of the differences between the moderators was addressed. In this process, five moderator variables were identified that were thought to play a role in the average effect size were determined: (*i*) the school level in which the survey was conducted, (*ii*) year, (*iii*) national culture (Hofstede, Hofstede, & Minkov, 2010), (*iv*) continents and (*v*) the Human Development Index (UNDP, 2018).

FINDINGS

Findings Related to Publication Bias

The funnel plot of the studies included in the meta-analysis, which was performed to determine whether there was a publication bias in the study, is presented in Figure 1. As the figure illustrates, no effect was found arising from publication bias in the studies included in the analysis; no evidence was observed with respect to publication bias of the 336 independent results that were included in the meta-analysis.

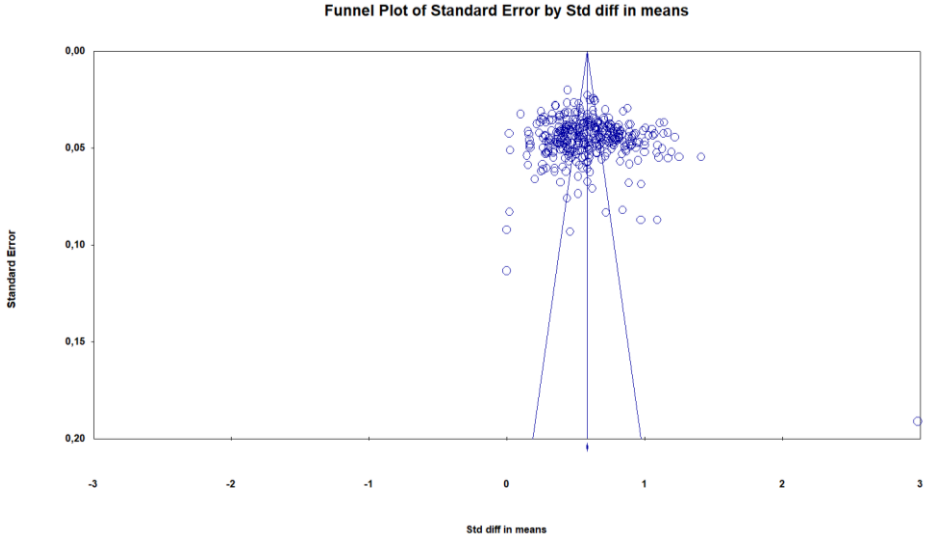

Figure 1
Funnel Plot of the Effect Size Related to Publication Bias

Although there was no evidence of publication bias in the funnel plot, a *Trim and Fill test* was performed to evaluate the extent of the effect related to publication bias in the effect size obtained as a result of the meta-analysis performed according to the random effects model. According to the results, which are presented in Table 1, there was no difference between the observed effect size and the virtual effect size created according to the random effects model, which was carried out to correct for any effect caused by publication bias. This demonstrates that there was no publication bias.

Table 1
Results of Trim and Fill Test

	Study	Point Estimation	CI (Confidence Interval)		*Q*
			Lower Limit	Upper Limit	
Observed values		.58	.56	.61	9928.6
Corrected values	0	.58	.56	.61	9928.6

Findings Related to Average Effect Size

The results of the meta-analysis showing the effect of students' self-confidence on 'mathematics achievement' are presented in Table 2. The findings support the H_1 hypothesis that self-confidence has an effect on students' mathematics achievement. The effect size of self-confidence on success (d) was calculated as .59, and it was statistically significant. This value shows that self-confidence has a moderate effect on mathematics achievement (Cohen, 1988). Moreover, the finding indicates that students with higher self-confidence demonstrate higher achievement in mathematics achievement than students with low self-confidence.

In H_2, we assumed that the school level, the year of the study, the national culture, the continent in which the countries were located, and the Human Development Index might be moderators for the effect of self-confidence on mathematics achievement. In the moderator analysis, the effect of self-confidence on mathematics achievement was found as follows

- There was no significant difference between school levels (*fourth grade* (d = .57) and *eighth grade* (d = .61) (Q_b = 2,689; p> .05).
- It increased significantly with the increase of the Human Development Index of the countries where the survey was conducted [*low (d = .30); medium (d = .37); high (d = .50) and very high (d = .65)*] (Q_b = 90.55; p <.01).
- It increased significantly according to the year of the survey [*2003* (*d*=.48); *2007* (*d*=.54); *2011* (*d*=.63) and *2015* (*d*=.67)] (Q_b= 34.11; *p*<.01).
- Regarding the continent where the country was located, it was significantly higher in Europe (*d*=.68) compared to the countries in the other continents (Q_b= 52.91; *p*<.01).
- It was significantly higher in horizontal-individualistic cultures (*d*=.64) compared to vertical-collectivist cultures (*d*=,56) (Q_b= 10.22; *p*<.01).

Table 2
The Effect of Self-Confidence on Mathematics Achievement: Results of the Meta-Analysis

Variable	k	N_{High}	N_{Low}	*d*	CI (Confidence Interval)		*Q*	Q_b
					Lower Limit	Upper Limit		
Mathematics Achievement	336	584.596	43.938	.59	.56	.61	9928.6*	
Moderator [School Level]								!.689
Fourth Grade	212	330.215	150.032	.57	.53	.60		
Eight Grade	124	254.381	293.951	.61	.57	.64		
Moderator [Culture]								
Vertical-Collectivist	218	355.343	312.519	.56	.53	.59		.0.22*
Horizontal-Individualistic	118	229.253	131.464	.64	.60	.68		
Moderator [HDI]								
Low	4	6.332	4.574	.30	.18	.42		)0.55*
Medium	33	59.529	53.701	.37	.30	.44		
High	74	125.746	97.420	.50	.44	.55		
Very High	209	371.973	264.692	.65	.62	.68		
Moderator [Year]								34.11*
2003	71	150.238	60.111	.48	.43	.54		
2007	85	188.365	61.541	.54	.49	.59		
2011	92	117.716	145.091	.63	.58	.68		
2015	88	128.277	177.240	.67	.63	.71		
Moderator [Continent]								52.91*
Africa	27	54.044	42.370	.42	.35	.50		
America	19	55.633	36.422	.53	.46	.60		
Asia	131	202.618	191.835	.54	.49	.58		
Australia	15	28.155	24.842	.55	.49	.61		
Europe	144	244.146	148.514	.68	.64	.71		

The review of the individual average effect sizes of 76 countries included in the study revealed that self-confidence had a significant effect on mathematics achievement in all countries. This effect was large in 11 countries, moderate in 36 countries and low in 29 countries. The countries with the highest effect were El Salvador, Malta, Bahrain and South Korea, respectively. The effect sizes according to the countries are presented in Table 3.

Table 3
The Effect of Self-Confidence on Mathematics Achievement According to Country

Country	*d*	Country	*d*	Country	*d*
Malta	1.14	United Arab Emirates	0.66	Iran	0.46
Bahrain	1.06	France	0.65	Russian	0.46
Korea	1.06	Latvia	0.65	Saudi Arabia	0.46
Cyprus	0.89	Spain	0.64	Lebanon	0.45
Slovenia	0.88	Estonia	0.64	Malaysia	0.45
Lithuania	0.85	Czech Republic	0.64	Botswana	0.45
Norway	0.83	Ireland	0.63	Scotland	0.42
Croatia	0.83	Qatar	0.62	Syrian	0.41
Poland	0.83	Italy	0.60	El Salvador	0.41
Portugal	0.82	Austria	0.60	Kuwait	0.41
Japan	0.82	Belgium	0.59	Algeria	0.41
Chinese Taipei	0.78	Slovak Republic	0.58	Bulgaria	0.40
Sweden	0.76	New Zealand	0.57	Morocco	0.39
Hungary	0.76	Jordan	0.56	Egypt	0.37
Canada	0.74	Georgia	0.55	Colombia	0.32
Finland	0.74	Australia	0.54	Armenia	0.31
Serbia	0.73	Singapore	0.52	Moldova	0.31
Denmark	0.72	Romania	0.52	Ghana	0.30
Northern Ireland	0.72	Israel	0.51	South Africa	0.29
Germany	0.70	Macedonia	0.50	Thailand	0.28
Ukraine	0.70	Palestinian	0.50	Azerbaijan	0.28
Netherlands	0.69	United States	0.49	Kazakhstan	0.25
Bosnia	0.68	Tunisia	0.49	Yemen	0.21
Oman	0.68	Hong Kong	0.49	Philippines	0.16
Turkey	0.67	England	0.49	Indonesia	0.10
Chile	0.67				

DISCUSSION AND CONCLUSION

In this meta-analysis study, where the effect of students' self-confidence on mathematics achievement was investigated, it was found that self-confidence has a positive and moderate effect. However, in this regard, no difference was found between primary and secondary school students. These results indicate that self-confidence is one of the important determinants of mathematics achievement. A growing body of evidence suggests that one's perception of ability or self-confidence is the central mediating construct of achievement strivings (National Research Council, 1994). Another finding of the study was that, with regard to the effect of self-confidence on mathematics achievement according to the year in which a study was conducted, the effect of self-confidence was found to be higher in more recent surveys. In this respect, the economic, cultural and social capital of students are very similar to each other as the economic levels of the countries and individual families increase. These similarities highlight the differences between students' personal characteristics, wherein traits such as self-confidence have become one of the most important variables that determine students' mathematics achievement in recent years. The results of the studies found in the existing

literature support this finding, as survey results show that self-confidence is significantly higher in students with high mathematics achievement (Hackett, 1985; Hackett & Betz, 1989; Hannula, Maijala & Pehkonen, 2004; Honicke & Broadbent, 2016; Hosein & Harle, 2018; Komarraju & Nadler 2013; Motlagh, et al., 2011; Pajares & Graham, 1999; Lent, et al., 1997; Pajares & Kranzler, 1995; Pajares & Miller, 1994; Waini, et al., 2014).

Moreover, self-confidence was seen to have a greater effect on students' mathematics achievement in countries with high levels of Human Development, in particular. In addition, the effect of self-confidence on mathematics achievement was found to be higher in horizontal-individualist cultures compared to vertical-collectivist cultures, as most of the countries with above average achievement rates from TIMSS were those with horizontal-individualistic cultures and high levels of Human Development. Since all of the variables (e.g., class size, school facilities, etc.) were equal in the education systems of these countries except students' personal variables (e.g., gender, attitude, self-confidence, liking mathematics, etc.), the effect of self-confidence on mathematics achievement was higher than in those with vertical-collectivist cultures and low Human Development, where there are greater disparities in terms of educational opportunities. Thus, in such countries, there are more variables that affect students' mathematics achievement (Yucel & Karadag, 2016).

This study was carried out using published data from primary studies. The greatest limitation of this research is that the data were drawn solely from difference studies; when research is based on differences between means, it is not entirely correct to argue that the results can fully explain the causal effects. In addition, the studies included in the meta-analysis were cross-sectional surveys, which indicates that a potential method bias may exist, as the studies included in the meta-analysis were limited to TIMSS and the data from the countries that participated in these surveys. Thus, similar individual studies that might have contained appropriate data for this study were excluded from the meta-analysis due to this limitation.

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