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The relationship between critical thinking and problem solving: A meta-analysis with correlational studies

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ABSTRACT

This study aimed to examine the relationship (direction and magnitude) between critical thinking and problem solving by combining the results of the studies carried out between 01.01.2015-30.11.2020 via meta-analysis. In this study, which is a meta-analysis study, PRISMA guidelines were followed. The studies obtained after searching the relevant literature through some electronic databases using search patterns were reviewed by two researchers in terms of inclusion criteria and 43 studies were included. Since more than one data were shared in some of these studies, meta-analysis was carried out with 49 data. The mean effect size of the relationship between critical thinking and problem solving was 0.483 under random effects model which indicated that there was a medium relationship between critical thinking and problem solving. This effect size did not differ according to sub-groups of region, critical thinking type, level of schooling, discipline and publication type. The results obtained in this study are confirmed by theoretical background regarding critical thinking and problem solving and previous studies.

Keywords: Critical thinking, problem solving, meta-analysis, correlation, higher-order thinking skills.

Eleştirel düşünme ile problem çözme arasındaki ilişki: Korelasyonel çalışmalar ile bir meta-analiz

ÖZ

Bu meta-analiz çalışmasının amacı 01.01.2015-30.11.2020 tarihleri arasında yapılmış çalışmaların sonuçlarını birleştirerek, eleştirel düşünme ile problem çözme arasındaki ilişkiyi (yön ve büyüklük) araştırmaktır. Arama terimlerini kullanarak bazı elektronik veri tabanları aracılığıyla ilgili literatürün araştırılmasının ardından elde edilen çalışmalar dahil edilme ölçütleri açısından iki farklı araştırmacı tarafından incelenmiş ve analize 43 çalışma dahil edilmiştir. Bu çalışmaların bazılarında birden fazla veri paylaşıldığı için, meta-analiz 49 veri ile gerçekleştirilmiştir. Eleştirel düşünme ve problem çözme arasındaki ilişkinin etki büyüklüğü 0.483 olarak bulunmuştur ve bu değer eleştirel düşünme ile problem çözme arasında orta düzeyde bir ilişkinin olduğunu göstermektedir. Elde edilen bu etki büyüklüğü çalışmanın yapıldığı bölge, eleştirel düşünme türü, sınıf düzeyi, alan ve yayın türü alt gruplarına göre farklılaşmamaktadır. Araştırma kapsamında elde edilen sonuçlar, eleştirel düşünme ve problem çözmeye ilişkin teorik alt yapıyla ve geçmiş çalışmaların sonuçlarıyla örtüşmektedir.

Anahtar kelimeler: Eleştirel düşünme, problem çözme, meta-analiz, korelasyon, üst düzey düşünme becerileri.

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1 | INTRODUCTION

Today, the main purpose of education is no longer to have individuals with basic knowledge, but to have individuals who can think effectively and are independent learners (Kaeppel, 2021). Higher order thinking skills, one of the 21st century skills (Partnership for 21st Century Learning, 2009), correspond to analyze, evaluate and create levels of the revised Bloom taxonomy and allow the individual to interpret information, adapt it to new cases, analyze it and create something original by going beyond the routine (Anderson et al., 2001). In fact, every human being has the ability to think at a basic level by nature and this is the most basic feature of the individual. However, people with basic thinking skills will fail to interpret their environment and solve problems, and if the individual does not have higher order thinking skills, this thinking process will be biased, incomplete and erroneous (Nosich, 2011). Therefore, higher order thinking skills enable the individual to think effectively, to have the skills of this century and to keep up with the developments and innovations occurred in this age. Besides, the individual with higher order thinking skills can think more effectively, and in this thinking process, the individual has an active role, takes responsibilities and becomes a person who researches, solves problems, can make logical decisions and produce original products. For this reason, one of the primary purposes of education is to improve individuals' thinking skills in the 21st century (Al-Zou'bi, 2021; Van Gelder, 2005).

Paul (1990) defines critical thinking (CT) as a mode of thinking about any subject or content in which the individual evaluates whether the information is valid, logical and correct or whether the result obtained is reasonable. Beyer (1995) defines CT as a process of making a judgment about the quality of knowledge. Therefore, it is possible to consider CT as a careful and rational judgment or decision-making process (Facione, 1990). This process includes the evaluation of information, claims or judgments according to certain standards (Facione, 1998). According to Halpern (2003), CT is the employing necessary cognitive skills and strategies which increase the possibility of reaching desired results. In other words, CT can be seen as cognitive skills and strategies that individuals use in solving problems (Sternberg, 1999a). Some of these cognitive skills and strategies are questioning, problem solving (PS) (Watson & Glaser, 1964), analysis, evaluation, inference, reaching a conclusion (Facione, 2000), decision making (Halpern, 2003), synthesis, defining and solving the problem, reaching a conclusion and evaluating the results (Angelo, 1995). The process in which these strategies and cognitive skills are used is a purposeful, criteria-based and self-regulative process (Facione, 2000; Lipman, 1988). In this process, which is a logical thinking process (Nosich, 2011), individuals take responsibility, query, understand the logic of the questions, reach conclusions and believe in the results after evaluating them (Lipman, 1988; Nosich, 2011).

CT is directly related to many thinking skills. CT, which is a multifaceted thinking process, includes different thinking skills depending on the situation (Bittner & Tobin, 1998). However, although CT includes different thinking skills, it is not totally same with these thinking skills. CT, which can be considered as an umbrella for other thinking skills (Bittner & Tobin, 1998), is not just a decision-making skill, although it includes decision-making. In addition, although it includes the stages of PS, it is not just about PS skills. Therefore, even if it includes different thinking skills in different problem situations, it is wrong to limit CT to a single thinking skill. On the other hand, other thinking skills also include CT in their own processes. For example, creative thinking skill can be employed in the CT process, and CT skills are used in the evaluation of the product or idea that emerges in the creative thinking process (Sternberg, 1999b).

CRITICAL THINKING and PROBLEM SOLVING

When problem is defined as the difference between the existing and the desired state or the difficulties need to be overcame by individuals in the journey of reaching this desired situation (Bransford & Stein, 1993), PS can be seen as the work of bringing out the most useful solutions to eliminate these difficulties/problems faced by individuals (Morgan et al., 2017). PS, which is a complex cognitive skill, involves skills such as reasoning and establishing cause and effect relationships (Açıkgöz, 2016). PS can also be defined as the cognitive activities used by individuals to reach a certain aim (Anderson, 1993) such as realizing the problem, examining the problem in all its aspects, collecting information and data regarding the solution, generating alternative solutions, evaluating alternatives and choosing the best solution (Kaya, 2008).

While the aim of PS is moving from an undesired situation to a better one, the main purpose of CT is not only to find a solution to a problem, but to collect evidence to defend thoughts, claims and judgments, to evaluate the

source of the collected evidence and to present it logically (Hickman, 1993). Therefore, while PS aims to solve the problem encountered, CT is not only about this and goes beyond PS (Meyers, 1998). While the result is important in PS, CT focuses on the process rather than the result. CT is needed during the whole PS process. According to Paul and Elder (2001), CT skills are employed in defining the problem, revealing the reasons and assumptions behind it, comparing different ideas on its solution, collecting information, data and evidence to reach a solution, and evaluating the source of this information, data and evidence. According to Fisher (2005), both CT and creative thinking skills are employed in the PS process. CT skills are needed in defining the elements of the problem, analyzing the problem rationally, comparing the alternatives to solve the problem and selecting the most appropriate and useful one. In short, while PS deals with a solution for a problem, CT focuses on all stages of the process and also includes evaluating the solutions which appear at the end of PS process.

Regarding the existent literature, there are many studies which suggest that CT is significantly related to PS (Irwanto et al., 2018; Kim & Choi, 2014; Kousar & Afzal, 2021; Kutluca, 2018; Memduhoğlu & Keleş, 2016; Shim et al., 2019; Tümkaya et al., 2009). On the contrary, there are also other studies which concluded that CT is not significantly related to PS (Demiral, 2019; Friedel et al., 2008; Gülünay, 2016; Junsay, 2016). Therefore, it is possible to say that studies on these issues have revealed some ambiguous results. In addition, the studies have yielded different results regarding the magnitude of the significant relationships found between CT and PS. So, meta-analysis studies on the relationship between CT and PS can offer a holistic portrait of the association between these thinking skills because meta-analysis studies allow the knowledge accumulated in a specific area to be interpreted in a consistent way by combining the results of previous research conducted by diverse people (Hunter & Schmidt, 1990). This study aimed to investigate the relationship (direction and magnitude) between CT and PS by combining the results of the studies carried out between 01.01.2015-30.11.2020 via meta-analysis. To this end, answer to the following question was sought for:

1. What is the relationship (direction and magnitude) between CT and PS skills and does this relationship vary by different variables?

2 | METHOD

In this study, which is a meta-analysis study, PRISMA guidelines proposed by Moher et al. (2009) were followed.

COLLECTION of STUDIES and INCLUSION and EXCLUSION CRITERIA

Studies found after literature review should be involved in the analysis in consideration of certain criteria (Springer et al., 1999). However, the criteria need to be set very carefully as qualities of the collected studies can decrease provided that the criteria are too broad while very few studies may be collected which may prevent the generalizability of the results if the criteria are too strict. Accordingly, inclusion criteria were determined firstly. Then, the studies were reviewed in terms of inclusion criteria by two different researchers.

According to Rosenthal (1979), one of the main problems in meta-analysis studies is publication bias (PB). Including only studies published in academic journals in meta-analysis is an important problem that may cause PB, since studies that have reached a significant difference or relationship results have more chance to be published in the academic journals than the others which concluded non-significant results (Rothstein et al., 2005). Therefore, including as many and different types of studies as possible in meta-analysis can prevent this problem that may cause PB and prevent obtaining more reliable and valid results. For this reason, it was aimed to include all studies that have focused on the relation between CT and PS and reported necessary statistical data in the analysis. So, studies published in the research journals, conference papers, book chapters and unpublished postgraduate theses are involved in the analysis.

The criteria which were used in order to examine the studies before including the meta-analysis can be seen below:

1. The study must be carried out between 01.01.2015 and 30.11.2020.

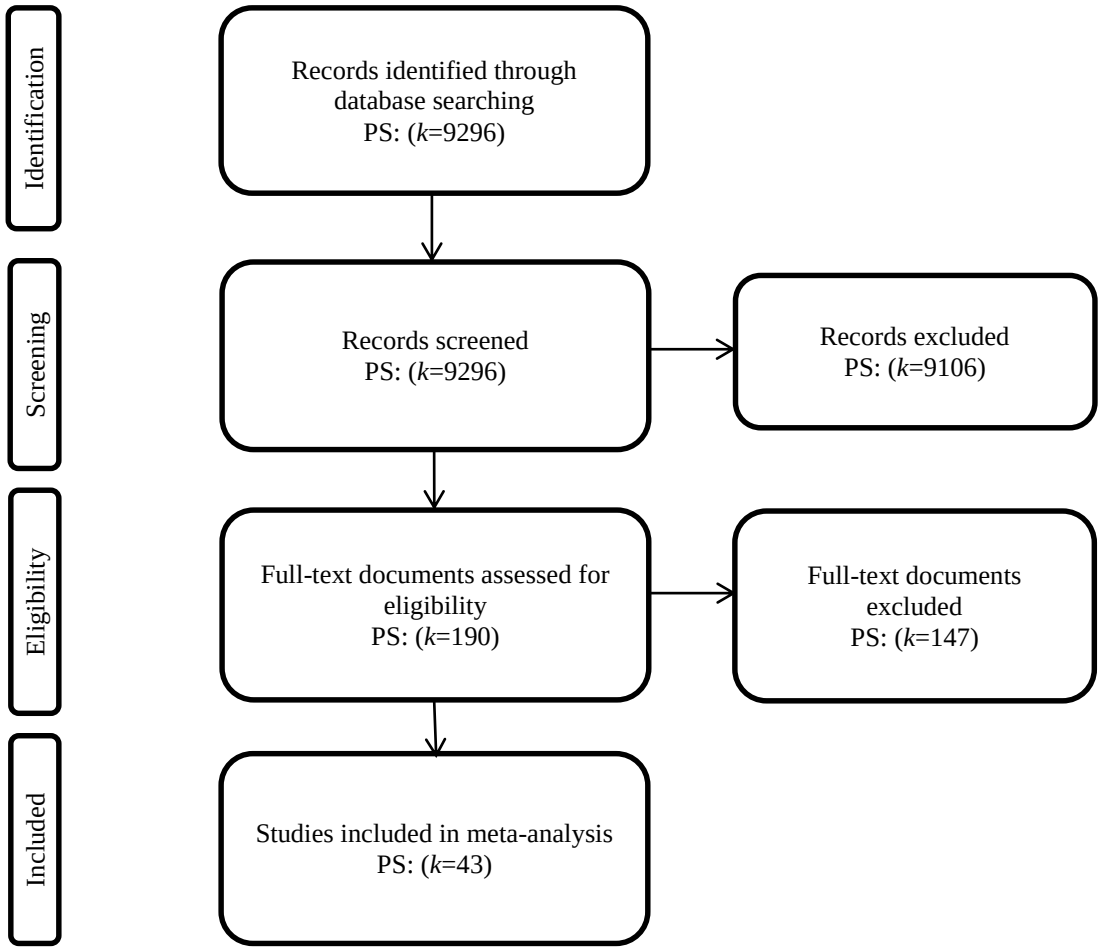
2. The study must be a correlational one which examines the relationship between CT and PS.

3. The measurement tools that have sufficient psychometric properties must be used in the studies.

4. The study must provide enough statistical data to estimate the ES.

In order to reach studies investigating the relationship between CT and PS, some online databases, namely, Google Scholar, Web of Science, Scopus, ULAKBİM and Turkish National Thesis Center were searched with "critical thinking" OR "critical thinking skills" OR "critical thinking disposition" AND "problem solving" OR "problem solving skills" search pattern in Turkish and English from 15.11.2020 to 30.11.2020.

The literature review resulted in 9296 studies in total. Firstly, the studies were investigated through their titles and abstracts and 9106 studies were eliminated due to some reasons (e.g., duplicates, not Turkish or English, etc.) Then, 190 studies were reviewed by two researchers and 147 of them were excluded due to some reasons (e.g., not a correlation one, did not report the necessary statistical data, etc.). Finally, 43 studies were included in the analysis. Since more than one data were shared in some of these studies, meta-analysis was conducted with 49 data (from 43 unique studies). Flow diagram for literature review can be seen in Figure 1.



PS: Problem solving skills

Figure 1. *Flow Diagram*

Then, the bibliographies of the collected studies were examined in detail and it was tried to reach other studies. However, no study that can be included in the analysis has been found. In short, total sample number of the studies included in meta-analysis was 11829.

CODING of STUDIES

The studies were coded with a coding form. The form contains information such as year of the study, name of the study, publication type (article, thesis, conference paper), author(s), sample characteristics, countries where

the study was carried out, the measurement tool used and the data required for ES calculations. The studies involved in the analysis were coded by two independent people (author of this study and a second person who has meta-analysis experience). Full consistency was seen between the coders (r=1.00).

DATA ANALYSIS and INTERPRETATION

The ES was calculated using Comprehensive Meta-Analysis (CMA) package program. The Pearson correlation coefficient and sample size information were used to calculate the ES. While calculating the ES, the Pearson correlation coefficient was first converted to Fisher's Z, analyses were made and then it was converted back to Pearson correlation coefficient. The confidence interval for the calculations was determined as 95% in this study. Upon deciding the level of ESs, less than 0.10, between 0.11 and 0.30, between 0.31 and 0.50, greater than 0.51 were adopted to be very weak, weak, medium and strong, respectively (Cohen et al., 2007).

PB, which is an important problem for the validity of the meta-analysis studies (Kromrey et al., 2006; Rothstein et al., 2005), should be checked before calculating the ES. In this study, funnel plot, Rosenthal's fail-safe N test, Duval and Tweedie's Trim and Fill, and Egger's regression intercept methods were used to check the PB.

According to Hedges and Olkin (1985), Q statistics can be used to investigate heterogeneity. Q value greater than the critical limit in X^2 table shows heterogeneity among studies. In addition, the I^2 value which may have values between 0% (indicates no heterogeneity) to 100% (indicates high-level heterogeneity) can also be used in checking heterogeneity (Petticrew & Roberts, 2006). Therefore, in this study, in order to decide whether there is heterogeneity or not, the obtained Q and I^2 values were examined.

Sub-group analyses were conducted according to sub-groups of region where the study was conducted, CT type (disposition or skill), level of schooling (primary school, secondary school, etc.), discipline (education, science etc.) and publication type (published or unpublished) using Analog ANOVA. With Analog ANOVA, we can compute various Q values such as between-group (Q_B), within-group (Q_W), and total (Q_{TOTAL}). Q_B value can be used to determine if the moderator variable is a real moderator or not (Lipsey & Wilson, 2001). Q_B value which is significant and less than the critical limit in X^2 table indicates that mean ESs vary between categories of the moderator variables.

3 | FINDINGS

RESULTS on PUBLICATION BIAS

Funnel plot and trim-and-fill methods were employed to check the PB. The funnel plot was shown in Figure 2.

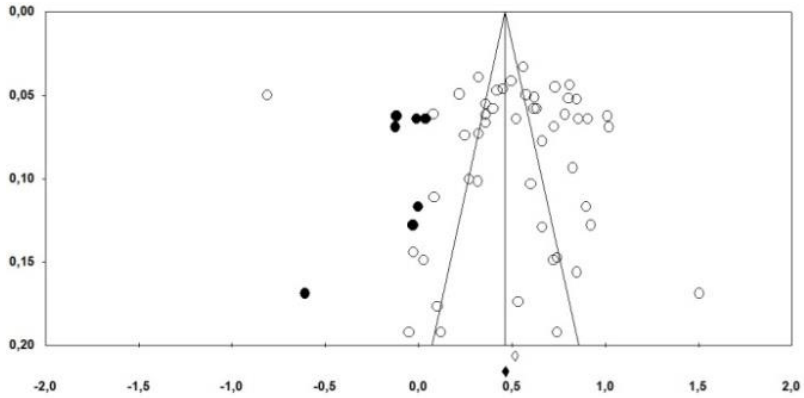


Figure 2. *Funnel Plot*

Empty circles in the funnel plots symbolize the studies involved in meta-analysis and the black ones refer to the imaginary studies which must be involved to eliminate PB totally (Duval & Tweedie, 2000). Also, symmetrically distributed funnel plot indicates no PB. As presented in Figure 2, we can say that the funnel plot seems symmetric. Furthermore, trim-and-fill method showed that only seven studies must be included to eliminate

the PB totally. Given the ESs were computed (49) in this study, it can be said that these imaginary studies can be neglected. Also, the fail-safe N number (33919) was much greater than the number (255) calculated using the formula of 5k+10 (Fragkos et al., 2014). Besides, Egger's intercept was 0.596 [95% CI=-3.233—4.426], p=0.755. Overall, we can say that there was no PB for this current study.

RESULTS on the RELATIONSHIP BETWEEN CRITICAL THINKING and PROBLEM SOLVING

Table 1 shows the ESs and the results of the heterogeneity tests in fixed and random effects models.

Table 1. ESs and Heterogeneity Test Results

Model	ES	*k*	SE	Z	%95 CI		df	Q	p	I^2
					Lower	Upper				
Fixed	0.475	49	0.009	55.724*	0.460	0.488	48	1381.45	0.000*	96.52
Random	0.483	49	0.051	10.323*	0.403	0.556				

*P<0.05

Note that the Pearson's r was first transformed to Fisher's Z, and after analyses were made, it was back transformed to Pearson's r and ES shows the Pearson's r values.

As seen in Table 1, in the random effects model, the ES was 0.483 [95%CI=0.403—0.556] with a standard error of 0.051. Also, the ES was 0.475 [95%CI=0.460—0.488] with a standard error of 0.009 in the fixed effects model. The data were also tested for heterogeneity and $Q_{(df=48)}$ value was found as 1381.45 ($p<0.05$). The obtained Q value was higher than the critical limit in X^2 table (df=48, $X^2_{(0.05)}$=65.171). Therefore, it can be said that there was heterogeneity among the studies. Also, as seen in Table 1, the calculated I^2 value (%96.52) showed a high level of heterogeneity. So, in this study, ES was calculated with random effects model. Indeed, as it is really hard to have homogeneity among the studies conducted in disciplines related to social sciences, meta-analysis with the studies from social sciences should always be conducted with random effects model (Schmidt & Hunter, 2015; Borenstein et al., 2009). The mean ES was calculated as 0.483 according to random effects model. Based on Cohen et al.'s (2007) benchmarks, this value showed that there was a medium and positive relationship between CT and PS.

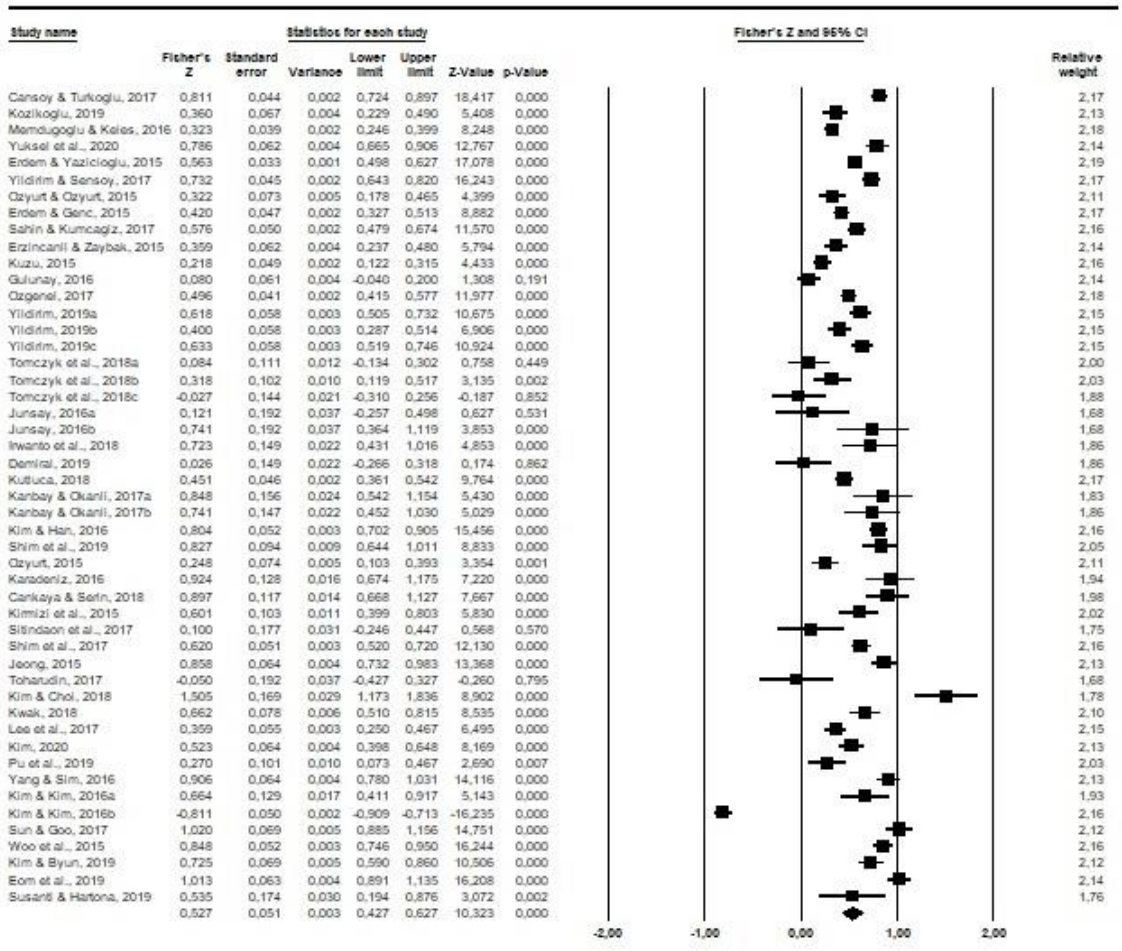


Figure 3. *Forest Plot*

According to the forest plot, Erdem and Yazıcıoğlu's (2015) study had the largest effect on the mean ES while Junsay's (2016) and Toharudin's (2015) studies had the smallest effect. Besides, out of 49 ESs, only three were negative. So it can be said that there was a positive relationship between CT and PS.

RESULTS on the SUB-GROUP ANALYSES

The results of the sub-group analyses are shown in Table 2.

Table 2. Results of the Sub-Group Analyses

Sub-groups		%95 CI			df	Heterogeneity test	
		k	ES	Lower Limit	Upper Limit	Q_B-value	p
Region	Asia-pacific	22	0.531	0.350	0.675	1	0.913	0.339
	Europe	27	0.441	0.374	0.505			
CT type	CT skills	10	0.323	0.107	0.509	1	3.340	0.068
	CT disposition	39	0.516	0.428	0.594			
Level of schooling	Elementary school	3	0.501	0.383	0.603	3	5.062	0.167
	High school	3	0.361	0.187	0.513			
	University	34	0.522	0.416	0.614			
	Adult	9	0.368	0.213	0.505			
Discipline	Education	15	0.450	0.347	0.543	1	1.650	0.199
	Health sciences	16	0.600	0.380	0.756			
Publication type	Published	42	0.495	0.403	0.578	1	1.279	0.258
	Unpublished	7	0.407	0.271	0.527			

Note that the Pearson's r was first transformed to Fisher's Z, and after analyses were made, it was back transformed to Pearson's r and ES shows the Pearson's r values.

As it can be seen in Table 2, the heterogeneity value of the sub-group of region (Q_B=0.913; p>0.05), CT type (Q_B=3.340; p>0.05), level of schooling (Q_B=5.062; p>0.05), discipline (Q_B=1.650; p>0.05) and publication type (Q_B=1.279; p>0.05) were less than the X^2 table critical values. So, we can say that there was not a statistically significant difference between the categories of the moderator variables. In other words, the magnitude of the relationship between CT and PS did not differ according to region, CT type, level of schooling, discipline and publication type.

4 | DISCUSSION & CONCLUSION

The aim of this study was to investigate the relationship (direction and magnitude) between CT and PS. For this purpose, the findings of the previous studies that are about the relationship between CT and PS were analyzed with meta-analysis method. After literature review, 43 studies that met the criteria to be included in the study were found and meta-analysis was carried out with 49 data (from 43 unique studies).

The ES of the association between CT and PS was found to be 0.483 and this ES did not differ according to sub-groups of region, CT type, level of schooling, discipline and publication type. Based on the views in the literature which state that CT and PS skills are closely related (Hickman, 1993; Fisher, 2005), we can say that a medium and positive relation between CT and PS is an expected result. According to MacPherson (1997) individuals' CT skills and dispositions are important in order to develop PS skills. In addition, CT dispositions are effective in PS activities (Barile, 2003) and CT skills are used while solving problems (Pereira, 2014). So, results of this study are confirmed by the previous research. Also, it is possible to find other studies concluding trainings designed to develop CT also improved PS (Işıklar & Abalı Öztürk, 2022; Kanbay & Okanlı, 2017; Shim et al., 2019). Therefore, the fact that activities designed to develop CT improve both CT and PS support the existence of a strong relationship between these higher-order thinking skills. In their study which aims to examine the relationships among CT dispositions, metacognitive awareness, and PS of students using structural equation model, Boran and Karakuş (2022) found that CT dispositions and PS are significantly related to each other. Also, Özgenel (2018) found that CT dispositions were a significant predictor of PS in his study. Similarly, Kutluca (2018) concluded that CT significantly predicted PS in his study aiming to investigate how some cognitive elements including CT affect PS skills. Besides, Orhan (2022) concluded that CT dispositions significantly predicted PS skills in his study. Besides, there are some other studies indicating CT and PS are closely related to each other (Kanbay & Okanlı, 2017; Lismayani et al., 2017; Pereira, 2014; Song et al., 2022). Therefore, we can say that the results of previous research support this study.

According to sub-groups analyses, we can say that both CT skills and dispositions are strongly related to PS and this relationship is constant for all school levels and disciplines. This can be seen as an important result because it shows us the close relationship between CT and PS at all school levels and disciplines. Also, it shows us that both CT skills and dispositions which are two main components of CT are significantly related to PS skills.

In short, it was found that there was a positive and medium relationship between CT and PS in this meta-analysis study. Previous literature indicated that CT is significantly associated with PS. The results of this meta-analysis study also support and contribute to this theoretical relationship. Therefore, it can be said that improvement of CT and PS skills should be aimed together in class because any improvement in one of these higher order thinking skills will also have positive effect on the other one.

LIMITATIONS AND IMPLICATIONS FOR OTHER STUDIES

This study has several limitations. Firstly, it is hard to decide the direction of the relationship between two variables with correlation studies. This limitation can be seen as an obstacle that limits correlation studies. Therefore, this can be shown as the first limitation of this study which aimed to calculate a general ES by using the results of correlation studies in the literature. In other words, it is impossible to answer the question of whether the PS skills are high because of high CT skills or whether the CT skills are high because of high PS skills. So, other studies should be carried out to reveal the association between CT and PS more clearly. Secondly, we can say that this study may have method bias because just correlational studies were involved in the analysis. So, the results of experimental studies can also be used in future meta-analyses. Lastly, this study is limited in its scope because it only included the studies carried out between 01.01.2015-30.11.2020.

CONFLICT OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A: Studies about the Relationship between Critical Thinking and Problem Solving Included in Meta-Analysis

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