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A Meta-Analysis of the Impact of Problem Posing Strategies on Students' Learning of Mathematics

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Abstract: This is a review of experimental research in which students have been taught to pose mathematical problems as a means of developing their learning. Hence, the aim of the research is to combine the empirical evidence regarding the functionality of problem posing strategies and to explore the aspects which could influence the integration of problem posing in mathematical education. In this direction, a meta-analysis approach was utilized in this study. 20 experimental research published between years of 2000 and 2020 are contained in this research and 31 effect sizes were computed. According to random effects model, it was found that problem posing strategy has significant impact on learners' problem-solving skills, mathematics achievement, level of problems posed, and attitudes towards mathematics (ES = 1.328; 1.142; 1.152; 0.643; p=0.05). These effects also were analyzed according to methodological and instructional variables. The findings obtained in the research was discussed in the light of the literature and suggestions were made for the future studies.

Keywords: *Problem posing; meta-analysis; learning outcomes; teaching mathematics.*

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1. Introduction

Due to its place in daily life and relationship to other disciplines, it is crucial that individuals should learn mathematics by integrating and using it in their daily lives. In line with this aim, firstly learners acquire mathematical knowledge and skills used in daily life, and then develop problem-solving skills and gain skills involving a problem-solving approach to problems (Altun, 2012). Problem solving is a process involving students understanding the problem given, making plans to ensure they can reach a solution, observing themselves during these processes, modifying strategy and plans when necessary, applying their plan, verifying the accuracy of their solution, attaching meaning to the solution when reached, analyzing benefits and becoming aware of new problems (Polya, 1973). Gonzales (1998) expressed that the problem posing approach should be the fifth stage of Polya's four-stage problem-solving process. El-Sayed (2002) stated that problem posing based learning contributed to establishment of the link between daily life situations and mathematics as well as that it was an effective approach to develop mathematical thinking of students. There is an enormous volume of published research delineating the importance and meaning of problem posing and there are a range of definitions about problem posing. For instance, problem posing was defined as a cognitive activity involving students producing new problems under certain conditions or generating new problems by modifying posed problem (Cai et al., 2015; Silver, 1994; Lavy & Shriki, 2007; Ticha & Hospesova, 2009). Problem posing was described as a process where, based on their experience, students developed personal explanations when faced with tangible situations and transformed these situations into meaningful mathematical ways (Stoyanova and Ellerton, 1996). According to Gonzales (1994), problem posing occurs by modifying the content of data in a solved problem or adding new information to a given problem.

With a long history, problem solving has gained an important place in curricula, but problem posing has not received enough interest (Ellerton, 1986). Few teachers give students the opportunity to regularly pose mathematical problems. Similarly, Stickles (2006) reported that teacher candidates had difficulty in generating novel problems relying on semi-structured and free problem posing circumstances. Stickles stated that this insufficiency was due to participants' lack of experience about problem posing and lack of theoretical knowledge. In fact, problem posing appears to be a noteworthy part of mathematics program, like problem solving, and is dominant to mathematical activities (El-Sayed, 2002; MEB, 2013; NCTM, 2000). Cai et al., (2015) expressed that today's mathematics education community observe problem posing as a tool encouraging problem solving skill, conceptual learning and creativity. Toluk-Ucar (2009) stated that mathematical problems formed during problem posing activities provided an idea about the mathematical insights, information, skills and beliefs of students. In addition, problem posing provide students with the improvement of reasoning, problem solving ability and is dealt with as an essential aptitude for problem solving in daily life (Kojima et al., 2015).

Problem posing activities are frequently seen as an effective teaching and learning approach of mathematics education in the relevant literature. In fact, the impact of problem posing-based mathematics teaching on learning outcomes were investigated by a variety of studies (Akay & Boz, 2009; Cankoy & Darbaz, 2010; Güzel & Biber, 2019; Chen et al., 2015; Guvercin & Verbovskiy, 2014; Turhan & Güven, 2014). Previous research has indicated that the utilize of problem posing-based approaches in education facilitates learning of mathematical concepts (Drake & Barlow, 2008; Van Harpen & Presmeg, 2013), increased critical thinking skills (Lowrie, 2002; Singer & Voica, 2012), developed cognition and metacognition like high-level thinking skills (Rosenshine et al., 1996), offered opportunities for problem solving (El Sayed, 2002), ensured development of problem posing skills (Chen et al., 2015; English, 1997; Suarsana et al., 2019) and contributed to development of positive attitudes and beliefs related to mathematics (Akay & Boz, 2010; Barlow & Cates, 2006; Chin et al., 2002; Sanchez-Elez et al., 2014; Turhan & Güven, 2014). Indeed, problem posing becomes more important than problem solving. With the increasing number of studies based on problem posing in latest years, it has become more important in the mathematics research. Researchers have investigated the development of mathematics classes by dealing with different problem posing variables. In this context, most researchers focused on studies comparing experimental environments involving problem posing with traditional environments. These studies investigated the effect of problem posing on different independent variables (skills, attitude, success, etc.) in the mathematics learning-teaching process. In fact, these variables are received from each outcomes of mathematical learning. It is thought that looking at the impacts of problem-posing on mathematical outcomes and how this effect changes from a broad viewpoint will contribute to the teachers who are the practitioners of the lesson. In this context, there is a need for a meta-analysis based on experimental studies about problem posing in mathematics education. In this regard, only two meta-analysis studies found in the literature directly address and measure the effectiveness of problem-posing. For example, Cantürk-Günhan, Geçici and Günkaya (2019) analyzed the findings of the experimental studies related to problem posing using the meta-analysis method in Turkey. The results of the study indicated that problem posing approach had positive and important impacts on student achievement. This research only concentrated on the effectiveness of problem posing method on student academic success and only included experimental studies conducted in Turkey. Finally, Rosli, Capraro and Capraro (2014) explored the effect of problem posing approach on outcomes of learning. This study included 14 studies from 1989 to 2011. The calculated effect sizes revealed that problem posing actions had significant for the sake of mathematics success, problem-solving ability, the levels of problem posed and attitudes about mathematics. However, the present research includes studies related to problem posing from 2000 to 2020 and therefore is more up-to-date. Problem posing is conceived to be a moderator variable determining the impact on mathematical learning outcomes. In line with this, who provides the education, how long it is applied for, how it is applied, which learning areas and which type of activities are used and the outcomes are important for researchers to increase the mathematical learning outcomes of students through design of learning settings.

1.1. The Aim of the Research

The aim of the research is to combine the empirical evidence regarding the functionality of problem posing strategies and to explore the aspects which could influence the integration of problem posing in mathematics education. Thus, a meta-analysis was used by combining the results of studies related to problem posing. Thus, the general effect size of problem posing on mathematical learning outcomes is calculated. Additionally, methodological and instructional moderator variables that may affect mathematical learning outcomes in the problem posing process are determined. As a result, variables that may affect mathematical learning outcomes in the problem posing process will be examined from a broad viewpoint via meta-analysis. The research question was raised as 'what is the impact of problem posing-based mathematics teaching on the mathematical learning outcomes of students?'.

2. Methodology

This research performed meta-analysis for systematic and integrated overview of studies unpublished and published and regarding mathematical learning outcomes from problem generation in the mathematics education context. Meta-analysis studies ensure systematic summary of a group of studies about a certain topic with the aid of statistical methods (Cooper, 2010).

2.1. Data Collection Process

Data were collected in 4 stages to assess the imapct of problem posing on mathematical learning outcomes in the mathematics education with the meta-analysis method. Literature review was performed in the first stage. After literature review, inclusion criteria were defined with the aim of determining which studies to include in the meta-analysis. Later, a coding form suitable for the aims of the research was created. Literature review was again performed according to the coding form. Thus, studies contained in the meta-analysis are determined.

The academic database of Web of Science, National Thesis Center, ProQuest Dissertations & Theses Global, ERIC and Google Scholar were used for the literature review. With the help of key words, the above databases were searched. Studies were identified at both title, abstract and key word level using the advanced search features of these databases. During scanning, expressions such as 'problem posing, 'problem writing' and 'problem generation and mathematics teaching' were used as keywords. As a result of this scanning, 339 studies were found. Though, 20 studies which suit the goal of the research were recognized. In this context, inclusion criteria were defined. The criteria related to inclusion of studies in this meta-analysis about problem posing are given in Table 1 with explanations.

Table 1. Description of criteria for inclusion

Criteria for inclusion	Description
Study area	Mathematics education research
Year of publication	Published between the years 2000-2020
Sample	A study applied to Primary schools, Middle schools, High Schools and Universities
Research Design	A posttest control group model
Learning outcomes	The outcomes were determined as a ability-based, attitude-belief, knowledge-based and skill-based. This categorization was used in

	the study of Rosli, Capraro and Capraro (2014) and they determined the variables necessary for the problem posing process.
Problem posing approach	Analyzing the utilization of problem posing based approach in mathematics teaching as an independent variable
Having sufficient numerical data	Inclusion of statistical data like sample size, standard deviation and arithmetic mean for both experiment and control groups

2.2. Coding Procedure

After the inclusion criteria in Table 1, control group non-experimental studies were removed from the meta-analysis. Additionally, when these studies were investigated, it was observed studies dealt with problem posing in terms of different variables. For example, for the 'ability-based' measure we named an intervention that had an effect on students' levels and the types of problem they created. Among these studies, learning outcomes about affective variables like mathematical attitudes and beliefs with problem posing were coded as 'attitude-belief'. Another mathematical learning outcome of 'knowledge-based' coded the success of students related to mathematical content. Stated differently, it may be considered the content knowledge related to mathematical content in problem posing. Finally, when learners might carry out some computation and apply problem-solving skills, we categorized the studies as a "skill-based". Thus, the ability-based, attitude-belief, knowledge and skill-based effects of problem posing were examined to see the broad perspective on mathematical learning outcomes. The impact of problem posing on each mathematical learning outcomes were separately investigated according to each outcome.

As a result, a coding form was created for more systematic scanning of research abiding by the inclusion norms. The coding form fully clarified the determination process for moderator variables when performing the meta-analysis. At first, decisions about which variables may change the impact of problem posing on mathematical learning outcomes were made according to the obtained literature. After the researchers determined the inclusion criteria according to this literature, the coding form was created. Elements on the coding form were written side by side and the studies were added below. Separate coding forms were used for each mathematical learning outcome. As a result, the same coding form was used for ability-based, attitude-belief, knowledge-based and skill-based outcomes; however, each was used separately. The coding form created in accordance with the aims of the research is given below.

Table 2. Coding form

A. Identification of the Studies
Author name-surname: Publication year:
B. Methodological characteristics of the study
B1. Publication type
Published Unpublished
B2. Experimental method used in the study
Posttest Pretest-Posttest
B3. Sample
Primary school - Middle school - High school Pre-service teacher
B4. Scale tool used in the study
Researcher developed Standardized
C. Instructional characteristics of the study
C1. Learning area
Numbers and processes Geometry and Measurement Data processing Mixed Not stated
C2. Form of preparation for problem posing activity
Strategy used Strategy not used
C3. Duration of activity about problem posing
5-10 hours 11-20 hours 21-30 hours over 30 hours

After literature review with the aid of the coding form given in Table 2, it was determined that 20 independent studies from 339 studies about problem posing abided by the inclusion criteria. The 31 effect sizes belonging to these 20 independent works were embraced in the synthesis. Later, the results of experimental works related to problem posing suitable for the meta-analysis were analyzed.

2.3. Analysis of Data

Statistical data for experimental works contained in the meta-analysis regarding problem posing were analyzed after coding with the coding form. For analysis of data, the study effect meta-analysis approach was used because when effect size linked to control and experiment groups for study efficacy is calculated, the mean difference between the groups represents the effect size (Malofeeva, 2005). Research determining effect size index is a type of meta-analysis (Kock, 2009). Study efficacy in the meta-analysis method uses standardized effect size index represented by 'd' or 'g' letters. In this study, the standardized mean difference method of 'Cohen's d' was used to calculate effect size. For interpretation of results, the classification of effect sizes related to arithmetic mean by Cohen (1988) was used.

According to Cohen's effect size classification, a value from 0.20 to 0.50 is small level, values from 0.50 to 0.80 are moderate level and values above 0.80 are broad level effect. To integrate results in meta-analysis studies, two types of statistical models of the fixed effects model and random effects model are used. The two model types are based on different assumptions about integrated effect size. The study being homogeneous or heterogeneous directs which model should be used (Borenstain et al., 2007). Analyses suitable for the aim of the research were performed using CMA Software.

2.4. Analysis of Moderator Variables

Moderator variables determining the impact of problem posing on mathematical learning outcomes were identified. The determination process for moderator variables gained clarity with the coding form. Before determining these variables, two main headings of methodological and instructional were created. Thus, methodological and instructional characteristics affecting the problem posing process were determined. Methodological and instructional characteristics were classified among themselves as given on the coding form (Table 2). Analysis of methodological and instructional variables determining the moderator variable were performed by considering the Qb (Q-between) values. This value is applied to identify important differences between moderator variables.

2.5. Publication Bias

It is definitely necessary to investigate publication bias in meta-analysis studies. As each method in meta-analysis studies has its own weak and strong aspects, different techniques should be applied to determine publication bias and to estimate the degree to which it affects results (Üstün & Eryılmaz, 2014). As a result, initially the Funnel Plot approach was applied to investigate publication bias about literature contained in the meta-analysis. Later, different publication bias tests were performed to decide whether publication bias existed or not. Figure 1 shows the funnel plot for each of the mathematical learning outcomes investigated in terms of the effect of problem posing.

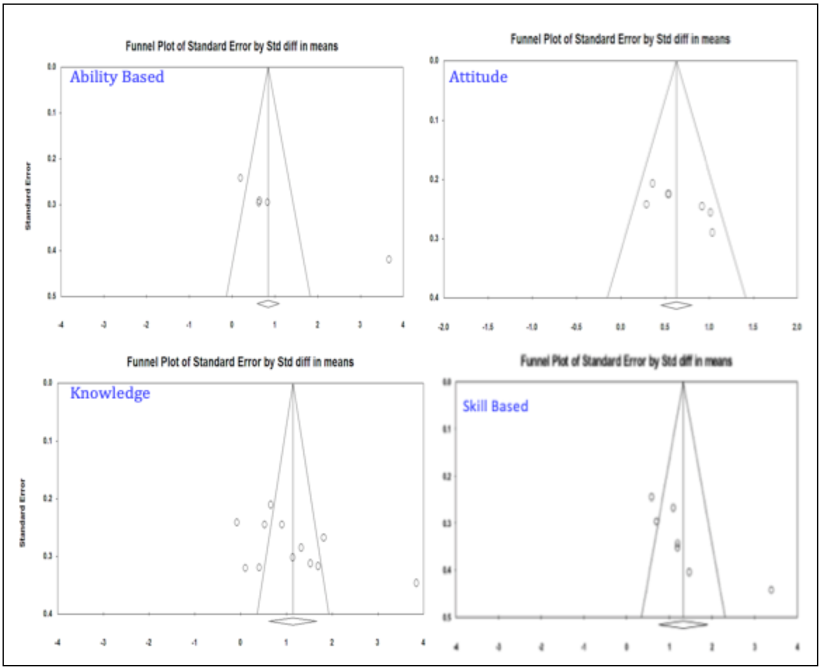

Figure 1. Effect size funnels related to publication bias

It appears that publication bias was not observed related to literature included in the meta-analysis on Figure 1. Publication bias is detected when the funnel plot displays severe asymmetry. Publication bias may be mentioned in situations where research is denser in the lower sections of the funnel especially, around the line showing the mean effect size (Çoğaltay et al., 2014). Though this meta-analysis study did not observe publication bias with regard to the funnel plot method, another publication bias method of the Duval Tweedie Trim and Fill test was performed. The findings of the above test are included on Table 3.

Table 3. Duval, Tweedie Trim and Fill test findings

	Mathematics Learning Outcome	**Point Estimate**	**95% CI**		**Q**
			Lower Limit	Upper Limit	
Observed Values	Ability-Based	1.152	0.191	2.133	53.581
	Attitude-belief	0.642	0.418	0.867	9.611
	Knowledge-b	1.141	0.615	1.668	123.665
	Skill Based	1.328	0.757	1.899	33.854

Adjustment Values	Ability Based	1.152	0.191	2.133	53.581
	Attitude-belief	0.642	0.418	0.867	9.611
	Knowledge	1.141	0.615	1.668	123.665
	Skill Based	1.328	0.757	1.899	33.854

According to Table 3, there is no change amongst the corrected values created to correct the effect of publication bias and the observed values. Finally, the classic fail-safe name test is applied to examine the publication bias of research involved in the process. Table 4 gives the findings of the classic fail-safe name test.

Table 4. Classic Fail-Safe Name

Resistance of Meta-Analysis versus Publication Bias	Mathematical Learning Outcomes			
	Ability	Attitude	Knowledge	Skill
z-value	7.464	1.178	13.495	10.254
p-value	0.000	0.000	0.000	0.00
Alpha-value	0.050	0.050	0.050	0.05
Alpha-value for z value	1.959	1.959	1.959	1.959
k	5	7	12	7
p>the number of missing studies for the alpha result	68	87	557	185

As seen in Table 4, so as to the results of this meta-analysis in this research to be invalid, it should be completed with 68 ability-based, 87 attitudes, 557 knowledge and 185 skill-based studies. Furthermore, the results of these studies should be contrary to those included in the meta-analysis. Considering all these results, it appears there is no publication bias in these meta-analysis results.

3. Results

In the current study with the purpose of investigating the effect size of problem posing on mathematical learning outcomes, 20 independent studies included in the meta-analysis were separated. These studies included a total of 2349 students. Of these 1091 were in experimental groups and 1258 were in control groups. As a result, different sample types in control and experimental groups were combined with the aim of reaching an integrated result in the meta-analysis. On account of this meta-analysis combining studies about problem posing, the heterogeneity values were observed to be high (for example, for knowledge [Q= 123.665; p < 0.05]). This value shows high levels of heterogeneity in the study (Cooper et al., 2009). In this context, a random model was used to research the effect on mathematical learning outcomes. The mean effect sizes and detailed confidence interval for studies contained in the synthesis with regard to the random effects model are included under the 'weighted effect size indices' heading.

3.1. Weighted Effect Size Indices

The random effects model was applied to combine the independent effect sizes of studies contained in this method. Thus, the weighted mean effect size for problem posing on the mathematical learning outcomes (knowledge-based, skill-based, ability-based, attitude-belief) was revealed. The forest graph showing the estimation interval related to effect sizes for mathematical learning outcomes is included in Appendix 1. The 95% confidence interval was calculated according to the estimated intervals related to the effect sizes. Later, the weighted mean effect sizes showing the effect of problem posing on the mathematical learning outcomes was calculated. The weighted mean effect sizes and confidence intervals showing the effect on mathematical learning outcomes are included in Table 5.

Table 5. Mean study-weighted effect sizes

Model Type	Mathematical Learning Outcomes	k	z	SE	Q	ES	95% CI		p
							Lower limit	Upper limit	
Random effects model	Ability Based	5	2.351	0.490	53.581	1.152	0.192	2.113	0.001
	Attitude	7	5.618	0.114	9.611	0.643	0.419	0.867	0.001
	Knowledge	12	4.252	0.269	123.665	1.142	0.616	1.668	0.001
	Skill Based	7	4.557	0.292	33.854	1.328	0.757	1.900	0.001

Note. Random Model; ES=Effect Size; SE= Standard Error; Q= total Heterogeneity value

According to the random effects model given in Table 5, the meta-analysis results for mean effect size were calculated as 1.152 for ability-based; 0.643 for attitude-belief; 1.142 for knowledge-based; and 1.328 for skill-based ($p<0.05$). In this context, the impact of problem posing during mathematics classes on attitude is positive and moderate level according to Cohen (1988), with positive and high level effects for ability-based, knowledge and skill-based outcomes.

3.2. Effect Sizes related to Moderator Variables

In the research, the methodological and instructional moderator variables determining effect size of problem posing on mathematical learning outcomes were examined. Methodological moderator variables were type of study, study method, group of sample in the research, and related to data collection tools used to measure academic success in the study. Instructional moderator variables were specific variables about problem posing within class. The instructional moderator variables included in the coding form were the learning area for the problem, problem type, preparation for activity ensuring problem posing and duration of activity about problem posing. Firstly, the methodological and then instructional moderator variables determining the effect of problem posing in mathematics lessons on mathematical learning outcomes (ability-based, attitude-belief, knowledge-based, skill-based) are given in order.

3.2.1. Effect Sizes related to Methodological Moderator variables

Table 6. Methodological moderator variables of Ability-based

MLO	Methodological moderator variable	k	ES	SE	95% CI		Qb	p
					Lower limit	Upper limit		
Ability-Based	Study type							
	Published	4	0.535	0.135	0.596	0.126	50.028	0.001
	Unpublished	1	3.670	0.419	2.848	4.492		
	Method							
	Post Test	1	0.829	0.295	0.252	1.407	0.352	0.553
	Pre-Post Test	4	1.24	0.638	-	2.497		

			6		0.004			
	Sample group							
	Primary school and Middle school	1	0.197	0.242	-0.276	0.671	3.441	0.064
	Preservice Teachers	4	1.408	0.606	0.220	2.596		

When Table 6 is investigated, it appears study type has a moderator role on ability-based learning outcomes [$Qb = 50.028$, $p < 0.05$]. That is to say, whether the study is published or unpublished changes the mean effect size for ability-based outcomes. However, it appears the study method and sample group do not have moderator roles [$Qb = 0.352$, $p > 0.05$; $Qb = 3.441$, $p > 0.05$]. Stated differently, the study being a posttest experimental study or a pretest-posttest experimental study did not change the mean effect size for ability-based outcomes, just as the study being performed with primary school students or preservice teachers did not change the effect size. All studies about ability-based outcomes used measurement tools developed by the researchers. Measurement tool was not included as a moderator variable for ability-based outcomes with the problem posing.

Table 7. Methodological Moderator variables of attitude-belief

MLO	Methodological moderator variables	k	ES	SE	95% CI		Qb	p
					Lower limit	Upper limit		
Attitude	Study type							
	Published	5	0.516	0.113	0.294	0.738	4.534	0.033
	Unpublished	2	0.964	0.177	0.616	1.311		
	Sample group							
	Primary school and Middle school	5	0.701	0.166	0.375	1.027	0.502	0.479
	Preservice teachers	2	0.537	0.159	0.226	0.849		
	Scale Tools							
	Researcher Developed	1	0.359	0.207	-0.046	0.765	2.005	0.157
	Standardized	6	0.700	0.123	0.459	0.941		

When Table 7 is investigated, it appears that study type has a moderator role for the attitude outcome [Qb = 4.534, p <0.05That is to say, the mean effect size on attitude changes if the study is published or unpublished. However, it appears sample group and measurement tool did not have moderator roles [Qb = 0.502, p > 0.05; Qb = 2.005, p > 0.05]. Performing the study with primary school, middle school or preservice teachers did not alter the mean effect size on attitude, while the form or preparation of the scale tool used in the study did not change the effect size. Additionally, all studies about attitude used the pretest-posttest model experimental pattern. In this context, study method was not included as a moderator variable affecting ability-based outcomes with the problem posing process.

Table 8. Methodological moderator variables of knowledge-based

MLO	Methodological Moderator variables	k	ES	SE	95% CI Lower limit	95% CI Upper limit	Qb	p
Knowledge	Study type							
	Published	3	0.845	0.141	0.568	1.122	0.926	0.336
	Unpublished	9	1.230	0.374	0.497	1.964		
	Method							
	Post Test	1	1.817	0.268	1.293	2.341	3.575	0.059
	Pre-Post Test	12	1.080	0.283	0.525	1.635		
	Sample group							
	Primary school & Middle school	10	0.808	0.181	0.453	1.163	3.815	0.051
	Preservice teachers	2	2.818	1.013	0.882	4.804		
	Scale Tools							
	Researcher Developed	10	1.199	0.289	0.633	1.765	0.113	0.736
	Standardized	2	0.865	0.948	-0.993	2.724		

From Table 8, it appears no methodological variables were effective on knowledge-based outcomes. As a result, it appears study type, method, sample group and scale tool did not have moderator roles for knowledge outcomes [Qb = 0.926, p > 0.05; Qb = 3.575, p > 0.05; Qb = 3.815, p > 0.05; Qb = 0.113, p > 0.05]. In other words, the effect size did not change whether the study was published or unpublished, used posttest model or pretest-posttest model, was completed with primary-middle school students or preservice teachers or based on the preparation form of the measurement tool used in the study.

Table 9. Methodological moderator variables of skill-based

MLO	Methodological moderator variables	k	ES	SE	95% CI Lower limit	95% CI Upper limit	Qb	p
Skill Based	Study type							
	Published	5	1.447	0.396	0.671	2.23	0.549	0.459
	Unpublished	2	1.040	0.380	0.295	1.786		
	Method							
	Post Test	1	3.397	0.442	2.531	4.264	27.509	0.001
	Pre-Post Test	6	0.973	0.135	0.709	1.238		
	Sample group							
	Primary school & Middle school	6	0.973	0.135	0.709	1.238	27.509	0.001
	Preservice teachers	1	3.397	0.442	2.531	4.264		
	Scale Tools							
	Researcher developed	6	1.312	0.330	0.665	1.960	0.095	0.758
	Standardized	1	1.473	0.405	0.679	2.267		

From Table 9, it appears some methodological variables were effective on skill-based outcomes. It appeared study type and measurement tool preparation did not have moderator roles for skill-based outcomes [Qb = 0.549, p > 0.05; Qb = 0.095, p > 0.05]. However, it appears study method and sample group had moderating roles [Qb = 27.509, p < 0.05; Qb = 27.509, p < 0.05]. In other words, effect size for skill-based outcomes changed depending on whether studies were completed with primary school students or preservice teachers and whether the study method was posttest experimental study or pretest-posttest experimental study.

3.2.1. Effect Sizes related to Instructional Moderator variables

Table 10. Instructional moderator variables of ability-based

MLO	Instructional Moderator Variables	k	ES	SE	95% CI Lower limit	95% CI Upper limit	Qb	p
Ability-Based	Learning Area							
	Numbers	2	0.633	0.207	0.226	1.039	0.787	0.675
	Mixed	2	1.917	1.736	-1.486	5.319		
	Not stated	1	0.829	0.295	0.252	1.407		
	Form of preparation for problem posing activities							
	Researcher	4	1.246	0.638	-0.004	2.497	0.352	0.553
	Textbooks & additional resources	1	0.820	0.295	0.252	1.407		
	Duration of problem posing activity							
	11-15 hours	2	2.234	1.420	-0.549	5.017	3.430	0.180
	16-20 hours	1	0.197	0.242	-0.276	0.671		
	Not stated	2	0.633	0.207	0.226	1.039		

When Table 10 is investigated, it appears the learning area for problem posing did not have a moderator role for ability-based outcomes [Qb = 0.787, p > 0.05]. Similarly, the form of preparation and duration of the activity about problem posing did not appear to have moderator roles

[Qb = 0.352, p > 0.05; Qb = 3.43, p > 0.05]. In other words, it can be said the type and duration of the activity about problem posing in mathematic lessons did not change the mean effect size for ability-based outcomes. Additionally, problem generating strategy was stated in all studies about ability-based outcomes. In this context, problem type was not included as a moderator variable affecting ability-based outcomes in the problem posing process.

Table 11. Instructional moderator variables of ability-based

MLO	Instructional Moderator Variables	k	ES	SE	%95 CI Lower limit	%95 CI Upper limit	Qb	p
Attitude	Learning Area							
	Numbers	3	0.463	0.133	0.203	0.724	4.927	0.177
	Data processing	1	0.917	0.246	0.236	1.399		
	Mixed	2	0.670	0.327	0.028	1.311		
	Not stated	1	1.037	0.290	0.469	1.605		
	Form of preparation for problem posing activities							
	Researcher	2	0.668	0.338	0.006	1.330	1.685	0.640
	Textbook	1	0.917	0.246	0.436	1.399		
	Textbook and additional resources	2	0.537	0.159	0.226	0.849		
	Not stated	2	0.648	0.362	-0.062	1.357		
	Problem Types							
	Strategy used	6	0.698	0.118	0.411	0.828	2.284	0.131
	Strategy not used	1	0.291	0.242	-0.184	0.765		
	Duration of problem posing activity							
	5-10 hours	1	0.291	0.242	-0.184	0.765	9.510	0.050
	11-15 hours	1	1.105	0.256	0.513	1.516		
	16-20 hours	1	0.359	0.207	-0.046	0.765		
	21-30 hours	2	0.967	0.187	0.600	1.335		
	Over 30 hours	2	0.537	0.159	0.226	0.849		

When Table 11 is investigated, it appears no instructional variables had moderator roles for attitude learning outcomes [Qb = 4.927, p > 0.05; Qb = 1.685, p > 0.05; Qb = 2.284, p > 0.05; Qb = 9.51, p > 0.05]. Stated differently, the mean effect size did not change for attitude with the learning area for problem posing, the use of any strategy for problem posing and the form of preparation and duration of the activity related to problem posing.

Table 12. Instructional Moderator variables of knowledge-based

MLO	Instructional Moderator Variables	k	ES	SE	%95 C) Lower limit	%95 C) Upper limit	Qb	p
Knowledge based	Learning Area							
	Numbers	6	1.364	0.515	0.857	1.403	7.623	0.106
	Geometry & Measurement	1	1.326	0.285	0.767	1.885		
	Data	1	0.902	0.245	0.421	1.382		
	Mixed	3	0.558	0.335	-0.099	1.214		
	Not Stated	1	1.694	0.515	0.354	0.273		
	Form of preparation for problem posing activities							
	Researcher	7	1.355	0.467	0.440	2.271	3.203	0.361
	Textbook	1	0.902	0.245	0.421	1.382		
	Textbook and additional resources	2	1.122	0.706	-0.262	2.505		
	Not stated	2	0.602	0.160	0.288	0.915		
	Problem Types							
	Strategy used	9	1.031	0.211	0.636	1.461	0.167	0.683
	Strategy not used	3	1.483	1.084	-0.641	3.608		
	Duration of problem posing activity							
	5-10 hours	2	0.366	0.202	-0.029	0.761	12.450	0.014
	11-16 hours	1	0.660	0.211	0.247	1.073		
	16-20 hours	3	0.604	0.483	-0.342	1.550		
	21-30 hours	4	1.926	0.606	0.739	3.113		
	Over 30 hours	2	1.494	0.337	0.833	2.155		

Table 12 appears to show that most instructional variables were not effective on knowledge outcomes. It appears the learning area for problem posing, preparation form for the problem posing activity and problem types do not have moderator roles for knowledge outcomes [Qb = 7.623, p > 0.05; Qb = 3.203, p > 0.05; Qb = 0.167, p >0.05]. In other words, these characteristics do not change the effect size for knowledge. However, the duration of the problem posing activity changes the effect size for knowledge [Qb = 12.450, p < 0.05]. Stated differently, the time spent on the activity about generating problems changes the effect size for knowledge. Additionally, it appears that the time spent on the activity planned for problem posing changes the effect size for knowledge outcomes. If more time is spent, the effect size on knowledge increases, which is among the notable findings in the research.

Table 13. Instructional Moderator variables of skill-based

MLO	Instructional Moderator Variables	k	ES	SE	%95 CI		Qb	p
					Lower limit	Upper limit		
Skill-Based	Learning Area							
	Numbers	3	0.999	0.190	0.628	1.371	26.04	0.000
	Geometry and Measurement	1	1.101	0.268	0.575	1.627		
	Mixed	2	0.832	0.210	0.420	1.245		
	Not stated	1	3.397	0.442	2.531	4.264		
	Form of preparation for problem posing activities							
	Researcher	3	0.794	0.155	0.490	1.097	4.628	0.201
	Literature	1	1.199	0.353	0.507	1.890		
	Textbook and additional resources	2	2.030	0.271	1.498	2.563		
	Not stated	1	1.473	0.405	0.679	2.267		
	Problem Types							
	Strategy used	6	1.444	0.337	0.783	2.106	2.696	0.101
	Strategy not used	1	0.706	0.298	0.123	1.289		
	Duration of problem posing activity							
	5-10 hours	2	1.317	0.266	0.795	1.838	29.998	0.000
	11-15 hours	1	3.397	0.442	2.531	4.264		
	16-20 hours	4	0.863	0.141	0.795	1.838		

Table 13 shows that some instructional variables are effective on skill-based outcomes. It appears the learning area for problem posing has a moderator role for skill-based outcomes [Qb = 26.043, $p < 0.05$]. In other words, the learning area for problem posing changes the mean effect size for skill-based outcomes. Similarly, the duration spent on problem-generation activities changes the effect size for skill-based outcomes [Qb = 29.998, p <

0.05]. However, it appears the preparation for the problem generating activity and the problem type do not change the mean effect size for skill-based learning [Qb = 4.628, p >0.05; Qb = 2.696, p >0.05].

4. Discussion

The aim of this study was to determine the general effect size in studies investigating the effect of problem posing-based mathematics teaching on the mathematics achievement, problem-solving skills, the levels of problem posed and attitude-beliefs about mathematics and to determine whether these effect sizes changed according to methodological and instructional characteristics. In this way, this study significantly contributes to understanding the effectiveness of problem posing strategy by investigating problem posing-based teaching in terms of four learning outcomes. The results of this meta-analysis study concluded that problem posing was effective on mathematical learning outcomes according to the random effects model. Accordingly, mean effect size on the mathematical learning outcomes was 1.152 for level of problems posed, 1.142 for mathematics achievement, 1.328 for problem-solving skills and 0.643 for attitudes towards mathematics ($p<0.05$). In this context, the impact of problem posing-based mathematics teaching on attitudes and beliefs of students about mathematics was at positive and moderate levels according to Cohen (1988), while the effects on mathematic success, level of problems posed and problem-solving skills were positive and at high level. According to data obtained from studies included in the meta-analysis, problem posing-based mathematics teaching can be stated to positively contribute to learning outcomes of students at high level. The present research findings showed that problem posing-based mathematics teaching was relatively more successful than traditional teaching methods in terms of four different learning outcomes. This result is consistent with individual research (Akay & Boz, 2010; Barlow & Cates, 2006; Chen et al., 2015; El-Sayed, 2002; English, 1997; Suarsana et al., 2019; Turhan & Güven, 2014).

Similarly, when meta-analysis studies in the literature are examined, it appears the effect of the problem posing-based approach in mathematics education on mathematical learning outcomes was investigated. For example, Rosli, Capraro and Capraro in a meta-analysis study in 2014 calculated 22 effect sizes for 14 studies and found the effect of problem posing-based teaching on level of problems posed was 0.77, attitudes and beliefs related to mathematics was 0.76, mathematics achievement was 1.31 and problem-solving skills was 0.83. The effect sizes calculated in this study and the effect sizes in the present study are similar. These values are positive and significant effect sizes according to Cohen's (1988) classification. Additionally, Cantürk-Günhan, Geçici and Günkaya, (2019) analyzed 14 effect sizes from 11 experimental studies related to problem posing in Turkey using the meta-analysis method. The study results calculated mean effect size value of 0.630 for student success with problem posing-based mathematics teaching. There is a consistent relationship between this meta-analysis study and the results of the other meta-analysis studies. In conclusion, this study found moderate and high levels of effect sizes for use of the problem posing-based approach in mathematics lessons for a variety of student variables (skills, attitude, success, etc.). Considering all these results, there were positive contributions to the learning outcomes for students identified when the use of the problem posing approach is compared to not using it.

Another result of this research is that methodological moderator analysis showed some methodological characteristics had significant differences for mathematics achievement. Similarly, when the 2019 study by Cantürk-Günhan, Geçici and Günkaya is investigated, analysis of methodological moderator variables for the use of problem posing-based approaches identified no significant differences in terms of publication time, educational stage and measurement tools. However, Rosli, Capraro and Capraro (2014) identified significant differences for educational stage and publication type for mathematical success as a result of methodological moderator variables. Additionally, in this study, some characteristics were found to display significant differences for attitudes to mathematics, ability to generate problems and ability to solve problems as a result of methodological moderator analysis. For example, the study being published or unpublished did not change the mean effect size for attitude to mathematics and problem-solving skills. Similarly, Rosli, Capraro and Capraro (2014) investigating the effect of the use of the problem posing approach in terms of problem-solving skills identified the effect size changes according to educational stage. In this research, application of the study to different educational stages changed the mean effect size for problem-solving skill of students. This may be due to the educational stage changing the effect on attitude to mathematics and problem-solving in the problem posing process so the attitudes and problem-solving differentiated according to education stage. In fact, in a meta-analysis study dealing with problem-solving as an independent variable found Kaya (2016) that as educational level increased in data from international studies, the effect increased for attitude to mathematics. For data from studies in Turkey, studies with students from middle school obtained higher effect size points. Similarly, other meta-analysis studies dealing with different independent variables (cooperative learning etc.) stated that educational stage changed the effect size for attitudes to mathematics (Capar & Tarim, 2015).

The results of instructional moderator analyses determined that instructional characteristics did not display significant differences for problem posing ability and attitudes. However, some instructional characteristics were determined to display significant difference for mathematics achievement and problem-solving skills. One of the instructional characteristics of duration spent generating problems was observed to change the mean effect size for success and problem-solving skills. The change in the effect size for success linked to duration spent on problem posing may be explained by success being a cognitive mathematical learning outcome. In fact, other meta-analysis studies dealing with different independent variables related to success and problem solving found duration affected success (Kul et al., 2018). However, duration in the problem posing process was not found to be effective on problem-solving in the study by Hembree (1992). The meta-analysis by Hembree (1992) found the duration spent on problems was not related to the problem-solving performance of students. The different result in this research may be due to problem posing being dealt with as the independent variable, because in the problem posing process, problem-solving is counted as a step so the duration spent on problems affected problem-solving skills. However, the reason for the duration not changing the effect size for problem posing ability and attitude to mathematics may be explained by ability and attitude being independent of time.

According to the meta-analysis results in this research, it was concluded that problem posing-based mathematics teaching has positive and significant effect on the mathematics success, problem-solving skills, ability to pose problems and attitude/belief related to mathematics of students. Teachers may benefit from the results of this study when deciding on teaching strategies to be applied in mathematic classes. According to the research results, increased time spent on problem posing was determined to increase success and problem-solving skills. In this context, mathematics teachers may spend more time on problem posing in lessons. This meta-analysis study only brings together experimental studies related to problem posing. Relational meta-analysis studies researching the correlations between problem posing and mathematical learning outcomes may be performed. Additionally, it is recommended that future experimental studies to research the efficacy of problem posing-based mathematics teaching be completed with larger sampling groups.

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Appendices A: Descriptions of studies included in the meta-analysis

Name of Study	Study Type	Sample	Dependent V.
Akay, & Boz, (2009).	Article	Pre-service	Knowledge
Akay, & Boz, (2010).	Article	Pre-service Teachers	Attitude-belief Attitude-belief
Cankoy, & Darbaz, (2010).	Article	3rd grade	Knowledge
Chen, Van, Dooren, Verschaffel, (2015).	Book Chapter	4th grade	Ability-based Skill-based Attitude-belief Knowledge
Demir, (2005).	Thesis	10th grade 11th grade	Attitude-belief Knowledge
El Sayed, (2002).	Article	Pre-service Teachers	Skill-based Ability-based
Fidan, S. (2008).	Thesis	5th grade	Skill-based
Guvercin, & Verbovskiy, (2014).	Article	8th grade	Knowledge
Guvercin, Cilavdaroglu, & Savas, (2014).	Article	9th grade	Attitude-belief
Güzel, & Biber, (2019).	Article	8th grade	Knowledge
Korkmaz, & Gür, (2006).	Article	Pre-service Teachers	Ability-based Ability-based
Keşsan, Kaya & Güvercin (2010)	Article	1-4th grade	Skill-based
Özdemir, Sahal, (2018).	Article	6th grade	Attitude-belief Knowledge
Priest, (2009).	Thesis	7th grade	Skill-based
Salman, (2012).	Thesis	6th grade	Skill-based

Tavşanlı, Kozaklı Ülger, Kaldırım, (2018).	Article	3rd grade	Skill-based
Toluk, (2009).	Article	Pre-service	Knowledge
Turhan, Güven, (2014).	Article	6th grade	Knowledge
			Skill-based
Yalçın, (2017).	Thesis	5th grade	Ability-based
Yıldız, (2014).	Thesis	Pre-service	Ability-based