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The Effectiveness of Student-Centered Teaching Applications Used In Determining Motivation Toward Science Learning: A Meta-Analysis Study

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ABSTRACT

The aim of this study was to determine the effect of student-centered teaching applications on students' motivation toward science learning with a meta-analysis study. For this purpose, national and international databases were scanned and master's theses, doctoral dissertations, and articles prepared between 2010 and 2020 were investigated. Accordingly, 271 studies conducted in Turkey were accessed, 59 studies were determined to meet the inclusion criteria, and the effect size of 61 was calculated. Using the Comprehensive Meta-Analysis v2.0 (CMA) Statistical Package program, the effect sizes and combined effect sizes of the studies were calculated. As a result of the analysis, the general effect size of different teaching applications on students' motivation toward science learning was determined as 0.620 (95% Cl, SE=0.088). This value was "medium level" according to the effect size classification of Cohen et al. (2007). As a result of the heterogeneity test, it was concluded that there was a high level of heterogeneity in the study (Q=408.198; ꩜^{2}=79.082; I^2=85.301). A moderator analysis was conducted to explain this heterogeneity between the effect sizes of the students' motivations toward science learning. For this purpose, categorical moderators (publication type, learning area, study location, grade level, scale type, and duration of applications) were determined to cause a statistically significant difference in effect sizes. According to the results of meta-regression analysis conducted for the moderators of publication year and sample size investigated as continuous variables in the study, publication year (z= -2.664, p<0.05) was found to cause a statistically significant difference in the effect size. Some recommendations were made in line with the study results.

Keywords:
Student-centered teaching applications, motivation for science learning, effect size, meta-analysis

1. Introduction

A constructivist learning strategy is based on the building of knowledge by students in a subjective way. In the learning environments suitable for this strategy, students are expected to construct knowledge by establishing a link between their old and new learning (Kalpana, 2014). In fact, the learning environments in which learning is made by the mental activities of students, scientific questioning is shaped by employing active learning strategies, and problems are solved by using high-level mental skills are defined as constructivist learning environments (Marlowe & Page, 2005). In these learning environments, learning models that allow the students to take responsibility for learning and to participate actively in the process are used. With the use of constructivist learning strategies and the learner-oriented learning models suitable for these strategies, the motivation concept affecting learning has gained importance (Glynn, Aultman, & Owens, 2005; Martin, 2001).

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1.1. Motivation

Motivation is an important affective factor that drives people toward a goal and allows them to achieve it decisively (Elliot & Covington, 2001; Glynn, Taasoobshirazi, & Brickman, 2009; Watters & Ginns, 2000). Brophy (1998) stated in this context that motivation is a theoretical concept that explains the direction and stability of behavior, and Watters and Ginns (2000) stated that it has a complex psychological structure that explains the effort in the actions. Therefore, the prominent feature of motivation is that it directs the person to certain goals and activates him/her in line with these goals (Demir & Budak, 2016).

Modern motivation theories aiming to determine how motivation affects learning put forward that motivation is multidimensional (Atkinson, 1957; Weiner, 1972). In this context, Paris and Turner (1994) point out four dimensions of motivation by stating that it changes according to the expectations and needs of the individual; individual evaluations are important; it depends on certain conditions; and it does not have a fixed structure. Besides, Ryan and Deci (2000) investigated motivation under three dimensions: intrinsic/extrinsic motivation and amotivation (Ryan and Deci, 2000). Intrinsic motivation focuses on the voluntary action of a person, while extrinsic motivation focuses on the result a person will get when he/she acts with the effects coming from the environment. Amotivation is the unwillingness of a person to do an action (Ryan & Deci, 2000) and is shown to be among the reasons why students fail in their classes (Okumuş, 2020). Therefore, it is important to increase students' learning motivation regarding courses (Wolters, 1999). One of these courses is the science societies attach the most importance to (Müezzin & Özata, 2019), and conducting high-level activities for students in this course and increasing the students' motivation to improve their conceptual science understanding is one of the most important educational topics (Cavas, 2011; Özarslan & Saraç, 2019).

1.2. Motivation and Student-Centered Teaching Applications for Science Learning

Science learning motivation can be defined as students' fulfillment of duties and responsibilities related to science (Lee and Brophy, 1996). It is stated that motivation is involved in many processes in science learning, from students' science achievements to conceptual change, scientific process skills, and the development of critical thinking skills (Chang, Hsu, & Jong, 2020; Tuan, Chin, & Shieh, 2005). In fact, it is also known that motivation toward science learning is effective on students' academic successes (Demir, Öztürk, & Dökme, 2012; Pintrich, 2003; Karakaya, Avgın, & Yılmaz, 2018). Besides, motivation toward science learning is affected by many factors such as the students' individual characteristics, learning styles, and learning environment (Meece, Glienke, & Burg 2006; Ng, Soon, & Fong, 2010; Pintrich & Schunk 1996; Yılmaz & Çavaş, 2007). Furthermore, the curriculum of the course and learning-teaching strategies and techniques used in the course also affect the students' motivation toward science learning (Lee & Brophy, 1996). In fact, active learning environments in which students are encouraged to use skills and processes related to questioning and can explore their own ideas positively affect their motivations toward science (Velayutham, Aldridge, & Fraser, 2012).

In order to increase the students' motivation toward learning science, it is necessary to consider individual differences and to arrange learning environments suitable for the students' expectations and needs. Teachers are people who guide students, form appropriate learning environments, and provide a positive learning environment for students in this process. Teachers using student-centered learning methods and techniques in their class can provide learning environments that will increase cooperation and solidarity and give the students the opportunity to increase their learning motivation, depending on the student's readiness level. The use of these methods and techniques is continuously increasing within the scope of constructivist learning strategies. On the other hand, when the studies investigating the effect of student-centered teaching applications in Turkey on the motivation toward science learning were examined, it was observed that different results were found. When the literature was reviewed, it was determined that cooperative learning models integrated with educational games (Yıldız, Şimşek, & Ağdaş, 2017), science experiments (Akıllı, Keskin, & Ay, 2017), cooperative learning (Doğru & Ünlü, 2012), educational games (Yenice, Tunç, and Yavaşoğlu, 2019), concept cartoons (Ayhan, 2017), project-based learning (Işık & Gücüm, 2013), problem-based learning supported with concept cartoons (İnel 2012), life-based learning (Demir, 2019), problem-based learning (Tekin, 2020), STEM (Yıldırım & Selvi, 2017), blended learning (Pesen & Oral, 2016; Meriçelli & Uluyol 2016), science notebook (Bıyık, 2016) and information graphs (Boyacı, 2019) positively affected students' motivation toward science learning. On the other hand, there are also studies in the literature stating that learning strategies and methods such as problem-based learning (Tekin & Yıldırım, 2020), blended learning (Gürdoğan and Bağ, 2019), technologically supported learning (Develi, 2017), material and experiment activities (Aytekin, 2018), REACT Strategy (Karaş & Gül, 2019), concept cartoons (Şahin, 2019), scientific stories supported by concept cartoons (Yılmaz, 2013), slow-transition animation technique (Çamloğlu, 2014; Pak, 2020) and STEM (Büyükpastırmacı, 2019; Parlakay and Koç, 2020) were found to have no effect on the students' motivations toward science learning.

1.3. Purpose of the Study

Although there are many studies in the literature stating different results on the effect of student-centered teaching applications on the students' motivations toward science learning, no meta-analysis study has been found on this subject. In this respect, it is necessary to analyze the studies again and make new decisions (Sağlam & Yüksel, 2007). This meta-analysis study will provide information about how effective different teaching applications are on the students' motivations toward science learning compared to traditional teaching methods and will reveal the general effect of different teaching applications on a national scale. On the other hand, the present meta-analysis study will also serve to clarify the inconsistencies in studies on the motivation of different teaching applications toward science learning. Based on these points, the answers to the following questions were sought within the scope of the study.

1) What is the general effect level of different student-centered teaching applications on motivation toward science learning compared to traditional methods?

2) Do the magnitudes of the effects of different student-centered teaching applications on motivation toward science learning differ significantly according to the study moderators?

2. Methodology

2.1.Research Model

This study was carried out using the meta-analysis method, one of the quantitative research synthesis methods. According to Lipsy and Wilson (2001), meta-analysis is one of the methods used to combine, interpret, and summarize data from scientific studies in any field.

2.2. Data Collection

Within the scope of the study, databases of "Eric, Science Direct, Web of Science, Dergipark, Google Scholar, Proquest, and YÖK (the Council of Higher Education) National Thesis Center" were used in the literature review to access the individual studies. While performing the literature review, the "motivation toward science, motivation toward science learning and scale/questionnaire for motivation toward science learning" keywords were used. Figure 1 illustrates the flow diagram showing how 59 studies were reached.

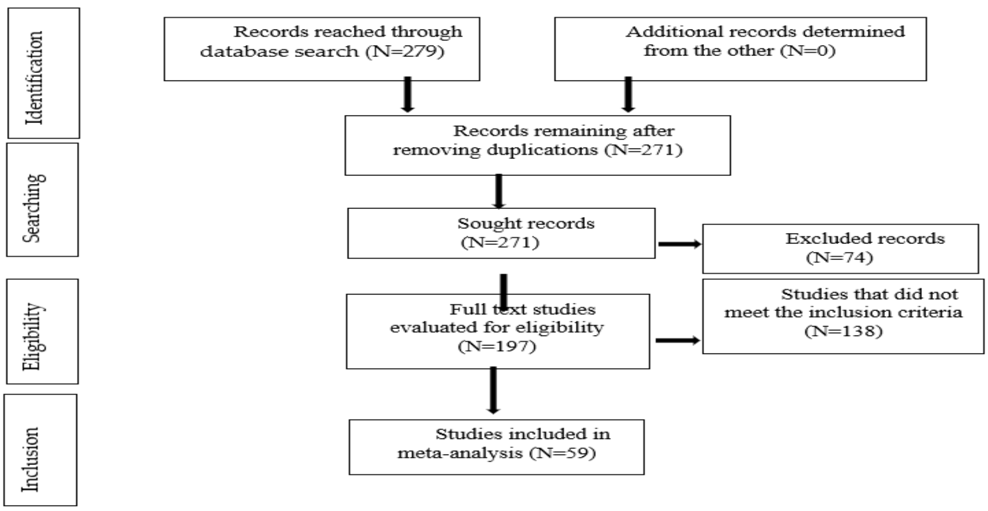

Figure 1. *Flow Chart for Selection of Studies*

As seen in Figure 1, as a result of the literature review and examinations, 279 national studies were accessed. Among these studies, it was found that there were 59 studies containing appropriate data and meeting the inclusion criteria [N=3997 (Experimental group=1995, Control group=2002)].

2.3. Criteria for Inclusion and Exclusion

While selecting the studies included in the meta-analysis, the following criteria were taken into account:

- Studies included in the meta-analysis were conducted between 2010 and 2020 in Turkey, and the sample group in these studies included primary school students.
- They were published or unpublished master’s and doctoral theses, articles in electronic academic journals, and papers presented in congresses and symposiums.
- In the studies to be included in the meta-analysis, the effect of student-centered teaching applications in the experimental group and traditional teaching applications in the control group on the motivation toward science learning was investigated.
- The motivation scale used in studies included in the meta-analysis was used to determine “motivation toward science learning.”
- In the studies to be included in the analysis, arithmetic mean, sample size, standard deviation, f, t, or p values were given to calculate the effect sizes.
- Studies to be included in the analysis were published in either Turkish or English.

In this meta-analysis study, studies in which the effect of student-centered teaching applications in the experimental group and traditional teaching applications in the control group on science learning was not investigated, international studies, single-group studies, qualitative studies, and descriptive review studies were determined as the exclusion criteria.

2.4. Data Coding

In the meta-analysis studies, explaining the literature review in full detail, recording the studies obtained as a result of the review process, using the coding form, and obtaining similar results by other researchers using the same steps affects the reliability (Card, 2012). In this study, a coding form consisting of three sections, including “study identity,” “study content,” and “data of the study,” was developed in order to record the studies reached as a result of the literature review. The content included in these sections is present in Table 1.

Table 1. *Content of Coding Form*

Study Identity	Study Content	Data of the Study
Study number	Education level	Arithmetic mean
Study title	Grade level	Standard deviation
Study author (s)	Scale used	Sample size
Publication year of the study	Teaching application	t value
Publication status	Sample size	p value
City where the study was conducted	Duration of applications	F value

In this study, the literature review was performed within the framework of the specified inclusion and exclusion criteria, and the studies reached as a result of the review were recorded in the coding form to ensure reliability. In addition, it is also recommended to ensure the reliability of the coding form in meta-analysis studies (Card, 2012; Petitti, 2000). In this study, agreement rate and Cohen’s Kappa statistics were used to determine the intercoder reliability. The intercoder agreement rate was calculated as 85.2%. It is stated that when the variables are categorical, the agreement rate can be affected by the chance factor and a rate higher than the expected one can be obtained (Hartmann, 1977). For this reason, it is recommended to use Cohen’s Kappa statistics, giving more reliable results against the chance factor (Card, 2012). The intercoder Kappa reliability value was calculated as 82.973. This value shows that there is a very good level of intercoder agreement according to the interpretation classification recommended by Landis and Koch (1977).

2.5. Analysis and Interpretation of Data

Effect sizes constitute the basis of meta-analysis. Effect size shows the sensitivity of an experimental procedure and the size of the experimental effect (Thalheimer and Cook, 2002). The combination of the effect sizes obtained from the individual studies to be included in meta-analysis is done by using statistical models. In the literature, two models, the"fixed effects model" and the "random effects model," are preferred. The fixed effects model assumes that there is only one effect size in all studies and the deviations in the effect sizes are caused by the sample changes (Card, 2012). The random effects model does not include the assumption that there is only one average effect size in the studies included in the analysis. Conversely, it assumes that the effect sizes in the studies vary and that this variation is caused by central tendency and study deviations (Card, 2012). Which one of these two models is used needs to be decided by the researchers before the analysis (Başol, 2016). In this study, the random effects model was preferred by considering factors like this study containing studies for different teaching applications and the applications being conducted in different cities.

While interpreting the effect sizes obtained as a result of the analysis conducted by using statistical models in meta-analysis studies, some classifications are used to interpret the level of the obtained results. There is more than one classification in the literature. According to Cohen et al. (2007), the effect size classification is as follows (2007):

- 0 ≤ The effect size value ≤ 0.20: the effect level is poor (poor),
- 0.21 ≤ The effect size value ≤ 0.50: the effect level is modest (modest),
- 0.51 ≤ The effect size value ≤ 1.00: the effect level is moderate (moderate),
- 1.01 ≤ The effect size value indicates that the effect level is strong.

One of the points that should be considered in meta-analysis studies is the publication bias. Publication bias is a situation caused by the tendency of studies that achieve statistically significant and positive results to not be published compared to negative and statistically insignificant studies. Depending on this situation, the average effect size value is likely to be high (Borenstein et al., 2009). In this study, the "Funnel Plot", "Orwin's Fail-Safe N", and "Egger regression intercept" methods were used to assess publication bias.

In the study, Q (Cochran's Q) and I^2 statistics were used to evaluate heterogeneity. Cochran's Q can be used as a measure of heterogeneity and is calculated as the sum of differences of the weighted squares between the effects of the individual studies and the effects of combined studies with the weights used in the combination method (Borenstein et al., 2009; Cochran 1950). I^2 statistic is a statistic that includes heterogeneity against the chance factor and shows the percentage of the variance in the studies included in the analysis (Higgins & Thompson 2002).

In the current meta-analysis study, the Comprehensive Meta-Analysis Version 2 (CMA Ver. 2.0) (Borenstein, Hedges, Higgins, & Rothstein, 2005) statistical package program was used for effect sizes, heterogeneity tests, moderator, meta-regression, and publication bias analysis. For the calculations for inter-coder agreement rate and Cohen's kappa statistics, the SPSS 22.0 package program was used. The value of 0.05 was accepted as a reference for the statistical significance value.

3.5. Ethical

In this study, all rules stated to be followed within the scope of "Higher Education Institutions Scientific Research and Publication Ethics Directive" were followed.

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3. Findings

3.1. Descriptive Statistics of the Meta-Analysis Studies

The distribution of subjects according to science fields of 59 studies included in the analysis and the learning areas of these subjects are presented in Table 2.

Table 2. *Subject Distributions of the Studies According To Science Fields and Learning Areas*

Science Fields *	Frequency (f)	Learning Area
Subjects in Biology (f=19)		
The systems in our bodies	8	Creatures and Life
The Cell Division and Heritage	2	
Exploring and Knowing the World of Living Creatures	2	
Living Creatures and Energy Relations/Living Creatures and Life	3	
Mouth and dental health	1	
Cells and divisions	2	
Global Warming, Sustainable Development and Bio-technology	1	
Subjects in Physics (f=22)		
Force and motion	4	Physical Events
Force and energy	1	
The electricity in our lives	7	
Work and energy	2	
Reflection and Light Absorption in Mirrors	1	
Light and sound	2	
The mystery of the earth's crust	1	Earth Universe
The solar system and beyond	4	
Subjects in Chemistry (f=13)		
The structure, properties, and nature of matter	10	Matter and Change
Matter and Heat	2	
Acids and bases	1	
Multiple Science Subjects (f=5)		
Human and Environment, Sun and Space	1	More than one
Structure and properties of matter, human and environment	1	
The Solar System and Beyond: Power and Energy	1	
Cell Division, Heritage, Force, and Act	1	
Exploring and Knowing the World of Living Creatures	1	

**The subject investigated was not specified in two studies.*

When Table 2 was examined, it was seen that biology subjects in 19 studies, physic subjects in 22 studies, chemistry subjects in 13 studies, and more than one science subject in 5 studies were studied. The systems in our bodies among the biology subjects; electricity in our lives among physics subjects; and the structure, properties, and nature of matter among the chemistry subjects were determined to be the most studied subjects.

Table 3 shows the teaching applications whose effect on students' motivation toward science learning in the experimental group was examined in the individual studies included in the meta-analysis.

When Table 3 was examined, it was observed that the effects of more than one different teaching application on students' motivation toward science learning were examined. Three studies were conducted from blended learning, cooperative learning, concept cartoons, the travel-observation method, STEM, context-based learning, problem-based learning, and project-based learning teaching applications; two studies were conducted from augmented reality, smart board, and educational games applications; and one study was conducted from other teaching applications.

Table 3. *Different Teaching Applications Used in Individual Studies*

Teaching Applications	Frequency
4MAT learning model	1
Allosteric learning model	1
Argumentation based	1
The ARSCS motivation method	1
Augmented reality	2
Blended learning	3
Brain-based learning approach	1
Cartoons in the teaching	1
Case-oriented station technique	1
Concept cartoons	3
The conceptual change method	1
Context-based learning	3
Cooperative learning	3
Creative drama activities	1
Cross-curriculum discipline	1
Drama	1
Educational games supported by computers	1
Educational games	2
Educational games integrated with a cooperative learning model	1
Game-based activities	1
Infographics	1
Inquiry-based learning	1
Instructional intervention focusing on scientific process skills	1
Material and experimental activities	1
Mobile-assisted	1
An online learning environment based on caricature animation	1
Problem-based learning	3
Project-based learning	3
Science book	1
Science, history and philosophy	1
Science stories supported with concept cartoons	1
Self-regulated learning strategies	1
Serious games	1
Slowmation application	1
Smart board	2
Social media-supported learning	1
STEM	3
STEM+Mastery learning	1
Technological pedagogical-based learning	1
Technology-enhanced flipped science classroom	1
Travel-observation	3
Web-based online virtual laboratory	1

Table 4 shows statistics of the publication year, publication types, study locations, grade level, scale type, and duration of application variables of the studies analyzed in this study.

When Table 4 was examined, the year 2019 according to the publication years, "article" according to the publication types, "Marmara" by regions, "7th grade" by grade level, "ready scale" by scale type, and "4-6 weeks" by the duration of applications were observed to be the subgroups in which the most studies were conducted.

Table 4. *Descriptive Results of Studies Included in the Meta-Analysis*

Study Characteristics	Frequency (f)
Publication Years	
2010	-
2011	2
2012	4
2013	6
2014	2
2015	6
2016	3
2017	14
2018	4
2019	15
2020	5
Publication Types	
Article	31
Doctoral Dissertation	3
Master Thesis	26
Proceeding*	1
Study Locations	
Mediterranean Region	7
Eastern Anatolia Region	6
Aegean Region	8
The Southeastern Anatolia Region	1
Central Anatolia Region	11
Black Sea Region	6
Marmara Region	16
Unspecified*	6
Grade Levels	
4th grade	5
5th grade	6
6th grade	14
7th grade	27
8th grade	7
6th + 7th + 8th. grades*	1
Unspecified*	1
Scale Types	
Adapted Scale	24
Ready Scale	37
Duration of Applications	
0-3 weeks	5
4-6 weeks	32
7-9 weeks	11
10+ weeks	5
Unspecified*	8

* These studies were not included in the moderator analysis.

3.2. Results About Publication Bias

In the current study, the "Funnel plot", "Orwin's fail-safe N", and "Egger regression intercept" methods were used to evaluate the publication bias. Figure 2 shows the "Funnel Plot" showing the publication bias results of 59 studies included in the analysis.

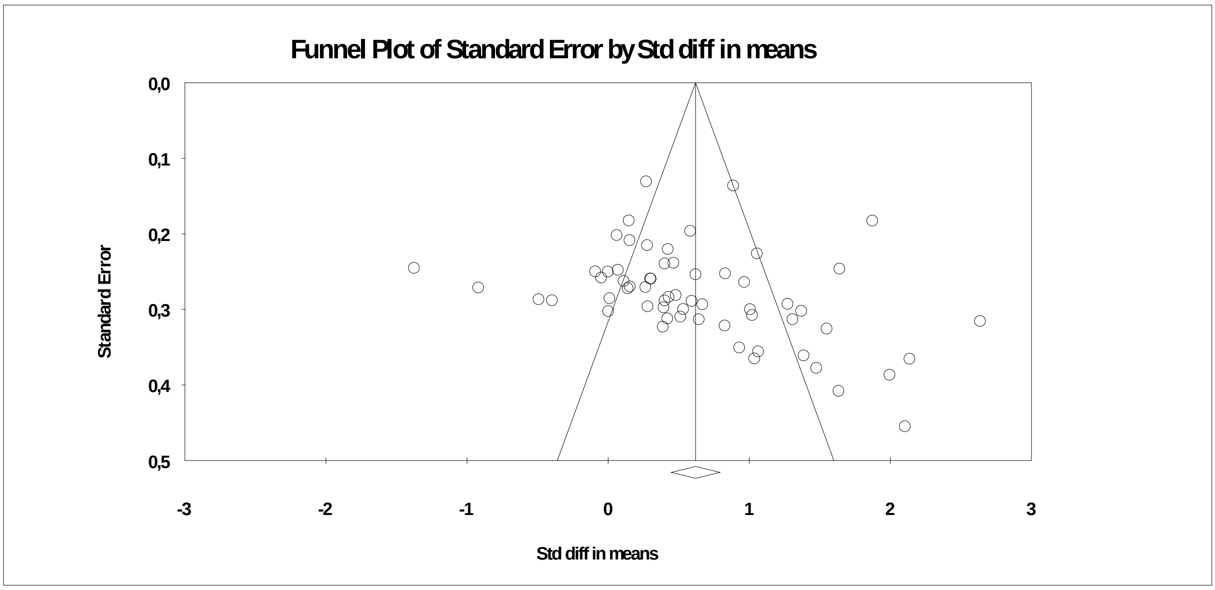

Figure 2. *Funnel Plot Publication Bias Results*

When Figure 2 was examined, it was observed that the studies showed an almost symmetrical distribution around the average effect size. This situation was interpreted as meaning that there was no publication bias (Borenstein et al., 2009). On the other hand, it is stated that the use of only the funnel plot in the evaluation of publication bias is not sufficient and it should be supported with other publication bias tests (Card, 2012). Therefore, the results for "Orwin's fail-safe N" and "Egger regression intercept" methods were also examined in the present study.

According to "Orwin's fail-safe N" result, a further 3309 studies should be conducted in order to reduce the average effect size of 0.620 to an insignificant level. Considering that 59 studies included in the analysis were conducted in Turkey, reaching 3309 studies is unlikely. According to the result of the "Egger regression intercept" method, p-value (2-tailed) was 0.098 and this value was not statistically significant.

When all results of publication bias are evaluated together, it can be asserted that there was no publication bias in this study.

3.3. Results Related to Effect Size

Table 5 shows the findings containing the effect size values, standard errors, lower and upper limit values of effect sizes, Z and p values of the teaching applications applied in the studies included in this meta-analysis with the general effect size of these teaching applications.

Table 5. *Effect Sizes and General Effect Size Results of the Teaching Applications*

Author(s) and Pub. Year	Teaching Applications	ES	SE	Lower Limit	Upp Limi	Z-valu	p-valu
Akgündüz and Akınoğlu, 2017-1	Blended learning	0.670	0.294	0.095	1.246	2.282	0.022
Akgündüz and Akınoğlu, 2017-2	Social media-supported learning	0.403	0.289	-0.163	0.968	1.395	0.163
Aktaş and Bilgin, 2015	4MAT learning model	0.272	0.131	0.015	0.529	2.072	0.038
Akyürek and Afacan, 2013	Brain-based learning approach	1.388	0.361	0.680	2.096	3.840	0.000
Arık, 2019	Science book	0.156	0.270	-0.373	0.686	0.579	0.563
Avcı, 2015	Cooperative learning	1.057	0.226	0.613	1.501	4.669	0.000
Aydoğdu, 2017	Argumentation based	0.425	0.221	-0.007	0.858	1.928	0.054
Ayhan, 2017	Concept cartoons	0.622	0.254	0.124	1.120	2.449	0.014
Aytekin, 2018	Material and experimental activities	-0.396	0.289	-0.961	0.170	-	0.170
Başarmak, 2013	An online learning environment based on caricature animation	0.534	0.300	-0.054	1.122	1.779	0.075
Berkant and Gökçedağ, 2019	Allosteric learning model	0.515	0.310	-0.093	1.122	1.659	0.097
Bodur, 2015	Travel-observation method	0.465	0.239	-0.003	0.933	1.948	0.051
Boyacı, 2019	Infographics	-0.047	0.258	-0.553	0.460	-	0.856
Büyükbastırmacı, 2019	STEM	-1.374	0.246	-1.855	-	-	0.000
Cengiz, 2019	Self-regulated learning strategies	0.390	0.323	-0.244	1.024	1.207	0.228
Demir, 2019	Context-based learning	1.309	0.314	0.695	1.924	4.176	0.000
Demirağ, 2014	Creative drama activities	0.932	0.351	0.244	1.620	2.655	0.008
Develi, 2017	Technological pedagogical based learning	0.063	0.202	-0.333	0.459	0.311	0.756
Doğru and Ünlü, 2012	Cooperative learning	0.001	0.250	-0.490	0.491	0.002	0.998
Ermiş, 2012	Smart board	1.039	0.365	0.323	1.755	2.843	0.004
Gürdoğan and Bağ, 2019	Blended learning	0.003	0.303	-0.590	0.597	0.011	0.992
Işık and Gücüm, 2013	Project-based learning	2.639	0.316	2.019	3.258	8.351	0.000
Keskin, 2019	Project-based learning	1.642	0.247	1.159	2.125	6.660	0.000
Kırıkkaya and Başgül. 2019	Augmented reality	0.301	0.260	-0.208	0.810	1.159	0.247
Pak. 2020	Slowmation application	0.113	0.263	-0.403	0.628	0.428	0.668
Parlakay and Koç, 2020	STEM	-0.089	0.250	-0.580	0.401	-	0.722
Yenice et al., 2019	Educational games	0.422	0.312	-0.190	1.035	1.351	0.177
Yıldırım and Selvi, 2017-1	STEM	0.431	0.284	-0.126	0.987	1.518	0.129
Yıldırım and Selvi, 2017-2	STEM+mastery learning	1.023	0.308	0.419	1.626	3.321	0.001
Yıldırım, 2020	Travel-observation method	1.274	0.293	0.700	1.849	4.348	0.000
Yıldız et al., 2016	Educational games	0.828	0.322	0.197	1.459	2.573	0.010
Yıldız et al.. 2017	Educational games integrated Cooperative learning model	1.371	0.302	0.778	1.964	4.534	0.000
İnel, 2012	Problem-based learning	0.305	0.260	-0.205	0.814	1.173	0.241
Durmaz and Mutlu, 2015	Instructional intervention emphasizing science process skills	0.645	0.314	0.031	1.260	2.057	0.040
Balaman and Tüysüz, 2011	Blended learning	0.967	0.264	0.449	1.485	3.660	0.000
Baran, 2013	Science, history and philosophy	0.282	0.296	-0.299	0.863	0.951	0.341
Çallı, 2019	Mobile-assisted learning	0.585	0.197	0.199	0.970	2.975	0.003
Esen and Onbaşılı, 2018	Concept cartoons	2.106	0.455	1.214	2.998	4.626	0.000
Karaş and Gül, 2019	Context-based learning	-0.918	0.272	-1.450	-	-	0.001
Karslı, 2015	The ARSCS motivation method	0.889	0.136	0.621	1.156	6.513	0.000
Keskin, 2011	Project-based learning	0.155	0.209	-0.255	0.564	0.740	0.459
Kılıç and Moralar, 2015	Problem-based learning	1.478	0.378	0.737	2.219	3.910	0.000
Meral, 2018	An online virtual laboratory	0.149	0.183	-0.209	0.507	0.815	0.415
Metin and Bozdoğan, 2020	Travel-observation method	1.635	0.408	0.835	2.436	4.005	0.000
Ormancı and Özcan, 2014	Drama	1.066	0.356	0.367	1.764	2.991	0.003
Özdemir and Dindar, 2013	Conceptual change method	1.008	0.300	0.419	1.596	3.357	0.001
Özgür and Yılmaz, 2017	Inquiry-based learning	1.997	0.387	1.238	2.756	5.159	0.000
Saracaloğlu et al., 2016	Cross-curriculum discipline	0.267	0.271	-0.264	0.798	0.985	0.325
Sezer, 2017	Technology-enhanced flipped science classroom	0.831	0.253	0.336	1.327	3.288	0.001
Sırakaya and Sırakaya, 2018	Augmented reality	0.279	0.215	-0.144	0.701	1.293	0.196
Tekin, 2019	Problem-based learning	0.395	0.298	-0.188	0.979	1.327	0.184
Tercan, 2012	Smart board	0.071	0.248	-0.415	0.558	0.288	0.773
Türe et al., 2020	Case-oriented station technique	0.403	0.240	-0.067	0.872	1.679	0.093
Ural et al., 2017	Cooperative learning	0.012	0.286	-0.548	0.572	0.042	0.966
Yazıcıoğlu, 2017	Game-based activities	0.482	0.282	-0.070	1.034	1.712	0.087
Yurttadur, 2019	Cartoons in the teaching	2.139	0.366	1.422	2.856	5.847	0.000
Yılmaz, 2013	Science stories supported by concept cartoons	0.142	0.273	-0.393	0.676	0.519	0.604
Özer, 2017	Serious games	1.875	0.183	1.517	2.234	10.25	0.000
Şahin, 2019	Concept cartoons	-0.490	0.287	-1.053	0.072	-	0.088
Şensoy and Gökçe, 2017	Context-based learning	0.595	0.289	0.028	1.162	2.056	0.040
Kahyaoğlu and Elçiçek, 2016	Educational games supported by computers	1.552	0.326	0.913	2.190	4.760	0.000
General Effect Size (Random Effects)		0.620	0.088	0.447	0.792	7.045	0.000

When Table 5 was examined, the general effect size value of the studies of different student-centered teaching applications combined under the random effects model was seen to be 0.620 with 0.088 standard error (lower limit of 0.447, upper limit of 0.792). This result showed that student-centered different teaching applications were effective at a "moderate level" on motivation toward science learning compared to the traditional teaching applications according to the classification of Cohen et al. (2007).

When Table 5 was examined, it was seen that the highest effect size value was 2.639 (Işık and Gücüm, 2013) and the lowest effect size value was 0.001 (Doğru and Ünlü, 2012) in the individual studies. It was determined that the effect size value was negative in 6 studies (in favor of the control group) and was positive (in favor of the experimental group) in 55 studies.

In the meta-analysis study, the heterogeneity test was performed to determine whether or not the effect sizes of individual studies had a homogeneous or heterogeneous distribution. Table 6 shows results related to this test.

Table 6. *Heterogeneity Test Results*

Q- value	Df(Q)	p	I² Value
408.198	60	0.000	85.301

When Table 6 was examined, it was seen that the Q value (408.198) of the studies included in the meta-analysis was higher than the 60 degree of freedom chi-square value (79.082) and that this value was statistically significant ($p<0.05$). This result indicated that there was a high level of heterogeneity between the studies included in the meta-analysis ($I^2=85.301$).

3.4. Results of Moderator Analysis

In meta-analysis studies, ANOVA similarity analysis for categorical moderators and meta-regression analysis for the moderators selected as the continuous variables are performed (Lipsey and Wilson, 2001). It is stated that the number of studies in each sub-group should be at least 2 in the ANOVA similarity analysis (Pincus et al., 2011). Therefore, the study groups with 1 subgroup in categorical moderators were excluded from the analysis. Besides, sub-groups of some studies could not be determined, and these were also excluded from the moderator analysis. In addition, in the current study, the effect of student-centered multiple teaching applications on motivation toward science learning was tried to be investigated. Since the frequency value of the teaching applications (see Table 3) was 1 in many teaching applications, moderator analysis could not be done. Therefore, it could not be determined which teaching application was more effective on motivation toward science learning or whether or not the effect sizes differed significantly among the teaching applications.

On the other hand, meta-analysis was conducted by considering the publication type, learning area, study location, grade level, scale type, and duration of applications as categorical moderators and by accepting analog ANOVA similarity analyses, publication year, and experiment sample size as continuous variables. Table 7 shows the ANOVA similarity results for the categorical moderators.

Table 7. *Results of the Categorical Moderators*

Moderators	Intergroup Homogeneity (QB)	p	k	Effect Size	95% Confidence Interval		Standard Error
					Lower Limit	Upper Limit	
Publication Type	1.986	0.159					
Article			31	0.722	0.489	0.954	0.118
Thesis			29	0.473	0.217	0.729	0.131
Learning Area	4.427	0.351					
Creatures and Life			19	0.611	0.320	0.902	0.148
Earth and Universe			5	0.533	0.163	0.904	0.189
Physical Events			17	0.311	-0.037	0.659	0.178
Matter and Change			13	0.778	0.417	1.139	0.184
More than one			5	0.751	0.401	1.101	0.179
Study Location	4.567	0.471					
Mediterranean			7	0.411	-0.030	0.912	0.240
Eastern Anatolia			6	0.810	0.542	1.078	0.137
Aegean			8	0.508	0.097	0.919	0.210
Central Anatolia			11	0.933	0.177	1.688	0.385
Black Sea			6	0.403	-0.207	1.012	0.311
Marmara			16	0.529	0.316	0.741	0.108
Grade Level	7.182	0.127					
Grade 4			5	0.994	0.163	1.824	0.424
Grade 5			6	0.260	-0.114	0.634	0.191
Grade 6			14	0.823	0.539	1.107	0.145
Grade 7			27	0.483	0.207	0.760	0.141
Grade 8			7	0.669	0.231	1.107	0.224
Scale Type	0.956	0.328					
Adapted			24	0.731	0.434	1.028	0.152
Ready			37	0.549	0.337	0.761	0.108
Duration of applications	2.320	0.509					
0-3 weeks			5	0.934	0.323	1.545	0.312
4-6 weeks			32	0.507	0.246	0.769	0.133
7-9 weeks			11	0.672	0.405	0.940	0.136
10+ weeks			5	0.751	0.401	1.101	0.179

When Table 7 was examined, the effect sizes of the individual studies investigating the effect of student-centered different teaching applications on motivation toward science learning were seen not to differentiate statistically significantly according to moderators of publication type (QB=1.986, p>0.05), learning area (QB=4.427, p>0.05), study location (QB=4.567, p>0.05), grade level (QB=7.182, p>0.05), scale type (QB=0.956, p>0.05), and duration of applications (QB=2.320, p>0.05).

In the current meta-analysis study, publication year and experiment sample size moderators were considered as continuous variables, and meta-regression analysis was performed for these moderators. Figure 3 shows the effect of the publication year moderator on the effect size.

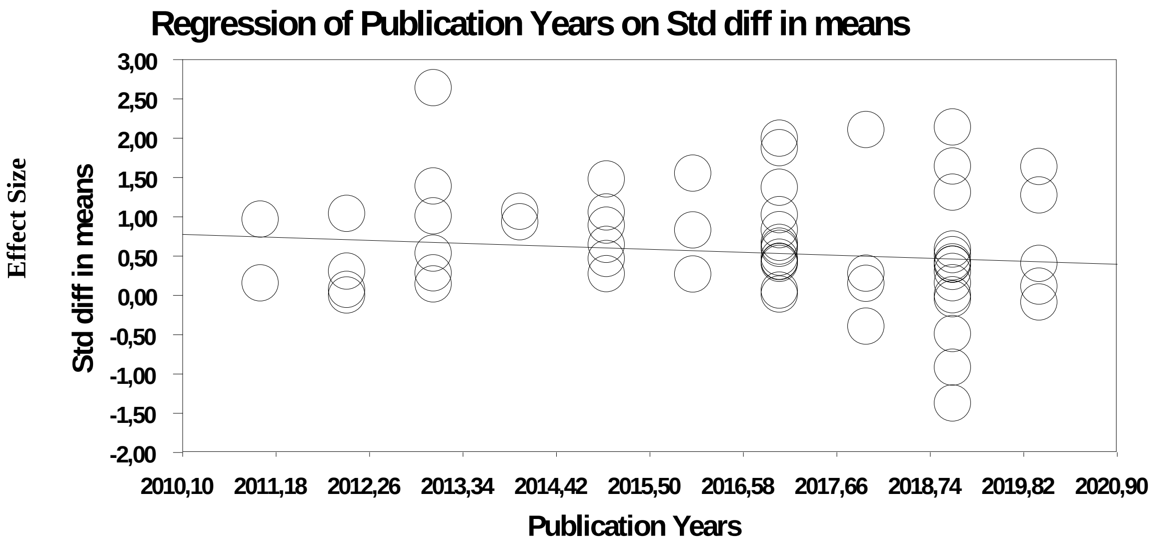

Figure 3. *Regression of Publication Years on Effect Sizes*

When Figure 3 was examined, it was seen that the slope of the regression line between the publication year and effect size decreased with the advancement of publication years toward 2020. Table 8 shows the results showing whether or not this decrease was statistically significant.

Table 8. *Results of the Effect of Publication Year on the Effect Sizes*

	Effect Size	Standard error	Lower Limit	Upper Limit	Z-value	p- value
Slope	-0.035	0.013	-0.061	-0.009	-2.664	0.007*
Intercept	71.431	26.566	19.302	123.561	2.685	

*p<0.05

When Table 8 was examined, it was seen that one unit increase in the publication year caused a decrease of 0.035 in the effect size, and this decrease was statistically significant ($p<0.05$). This result can be interpreted as the students' motivation toward science learning being higher in studies conducted in previous years.

The effect of the number of participants in the experimental group has on the size of the effect sizes in the individual studies investigating the effect of different teaching applications on the students' motivation toward science learning was examined by meta-regression analysis. Figure 4 shows the effect of experiment sample size on the effect size.

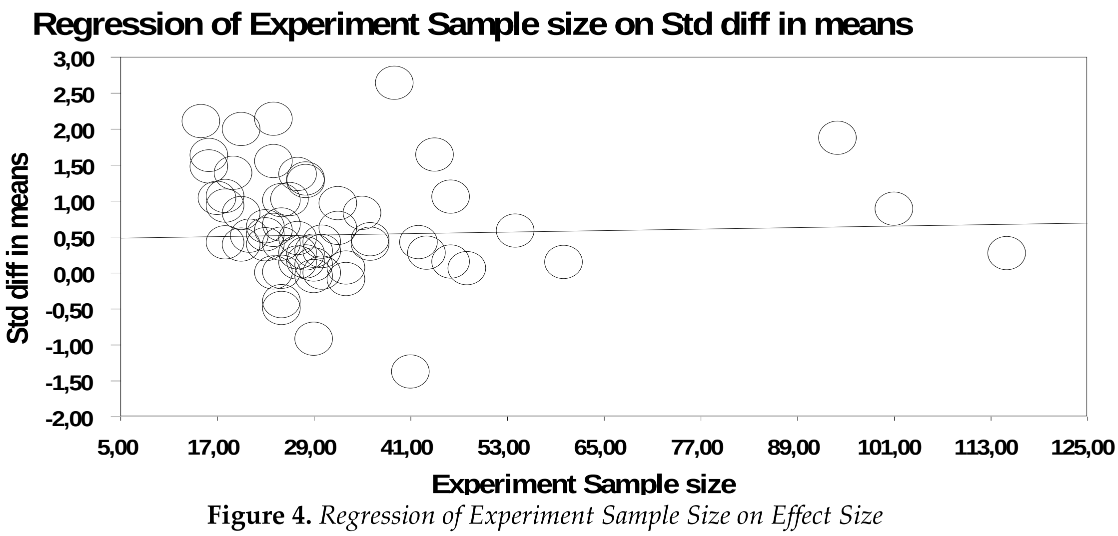

Figure 4. *Regression of Experiment Sample Size on Effect Size*

When Figure 4 was examined, it was seen that the slope of the regression line between the experiment sample sizes and the effect sizes increased with the increasing sample size. Table 9 shows the results showing if this increase was statistically significant or not.

Table 9. *Findings About the Effect of Experiment Sample Size on Effect Sizes*

	Effect Size	Standard error	Lower Limit	Upper Limit	Z-value	p- value
Slope	0.001	0.001	-0.0001	0.004	1.493	0.135
Intercept	0.476	0.060	0.356	0.595	7.826	

When Table 9 was examined, it was determined that one unit increase in the sample size of the experimental group caused an increase of 0.001 value in the effect size, but this increase is not statistically significant ($p>0.05$). In other words, the increase in the sample size of the experimental group did not cause a statistically significant increase in the effect size.

4. Conclusion and Discussion

Within the scope of the study, 59 studies investigating the effects of different teaching applications on students' motivation toward science learning were included in the meta-analysis. In the categorical descriptive characteristics of these studies, "article" according to publication types, "Creatures and Life" according to learning area, "Marmara region" according to study location, "7th grade" according to grade level, "ready scale" according to the scale used, "2019" according to the publication year, and "4-6 weeks" according to the duration of applications were the categories having the highest number of studies. In the current study, in which "Funnel plot", "Orwin's fail-safe N", and "Egger regression intercept" methods were used to evaluate the publication bias within the scope of the study, it was determined that there was no publication bias.

As a result of combining made under the random effects model, the average effect size value was determined as 0.620. According to the classification of Cohen et al., (2007), this result showed that different teaching applications had a "moderate level" effect on the motivation toward science learning compared to the traditional teaching applications. The highest effect size value of 2.639 was obtained with project-based learning applications in individual studies (Işık and Gücüm, 2013). The lowest effect size value was 0.001, which belonged to the cooperative learning practice (Doğru and Ünlü, 2012). It was determined that the effect size value was positive (in favor of the experimental group) in 55 studies. This result is parallel with the result of Kimonen and Nevalainen (2005) stating that active participation of the students increases their motivation. No meta-analysis study was found in the literature investigating the students' motivation toward science learning. In the study by Gür and Bulut-Özek (2021) entitled "The Effect of Mobile Learning on Students' Academic Achievement, Motivation, and Attitudes: A Meta-Analysis Study", the result indicates that mobile learning has a moderate level effect on motivation (Hedge's $g=0.541$) supports the current study result. In the study of Lazowski and Hulleman (2016) titled "Motivation Interventions in Education: A Meta-Analytic Review", the result showed that the average effect size value was at a small level ($d=0.49$) differed from the result of this study. On the other hand, a moderate level of effect was found in meta-analysis studies investigating the effect of some teaching applications on affective factors. In this context, Sitzmann (2011) determined a moderate effect level in his meta-analysis study investigating the effect of computer-aided simulation games on self-efficacy beliefs. In the meta-analysis study of Gegenfurtner, Veermas and Vauras (2013) who investigated the effect size of the correlation between the computer-aided cooperative learning and self-efficacy and teaching transfer, the correlation between self-efficacy and transfer after teaching was determined to be at a moderate level.

As a result of the heterogeneity test, it was concluded that there was a high level of heterogeneity in the study ($Q=408.198$; $\chi^2=79.082$; $I^2=85.301$). A moderator analysis was conducted to explain this heterogeneity between the effect sizes of students' motivation toward science learning. For this purpose, publication type, learning area, study location, grade level, scale type, and duration of applications were determined not to cause any statistically significant difference in the effect sizes of the categorical moderators. According to the meta-regression analysis results conducted for the publication year and experiment sample size moderators examined as a continuous variable, only the publication year ($z= -2.664$, $p<0.05$) moderator was found to cause a statistically significant difference in the effect size. In other words, it was determined that there was a statistically significant decrease in the slope of the line showing the correlation between the publication year and the effect size from 2010 to 2020. This result can be interpreted as the fact that students' motivation toward science learning was higher in previous studies. The reason for this situation could be the non-homogeneous distribution of the studies included in the meta-analysis in terms of publication year.

5. Recommendations

Since this meta-analysis study covers the studies conducted between 2010 and 2020, the study can be repeated by extending this time period in a new meta-analysis study.

When the frequency and percentage values of the studies included in the meta-analysis study according to publication type were examined, 52.54% of 59 studies were seen to consist of articles. The fact that there were only 3 doctoral theses on the effect of different teaching applications on motivation toward science learning reveals the necessity of increasing the number of such studies.

When the studies included in the meta-analysis were examined in terms of publication year, it was seen that the level of motivation toward science learning decreased from the past to the present. It can be recommended for researchers to investigate the reasons for this.

In the current study, studies in pretest–posttest design with a control group investigating the effect on the students' motivation toward science learning were included in the meta-analysis. It can be recommended to conduct a meta-analysis study including studies with a control group in a single group pretest-posttest design.

In this meta-analysis study, the effect of different teaching practices on students' motivation toward science learning was investigated, and the other effects were excluded from the scope of the study. Researchers may be advised to conduct studies examining the effects of different teaching applications on different affective characteristics such as permanence, motivation, self-efficacy, and scientific process skills.

The fact that all the research evaluated in the current study has been conducted in Turkey makes the effect size value valid for Turkey. In this context, the scope of the research can be expanded by conducting international studies. In addition, comparative meta-analysis studies can be conducted on the basis of countries.

It was seen in the study that especially concept cartoons, cartoons in teaching and project-based learning applications had a strong effect on the students' motivation toward science learning. These applications can be concentrated on in MEB programs.

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