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The Effects of Studies in the Field of Science on Scientific Process Skills: A Meta-Analysis Study

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In this research, a meta-analysis study was conducted to determine the effect of student and teacher-centered practices in science lessons on students' scientific process skills. To this end, the literature related to the studies conducted in Turkey and abroad was searched. For this purpose, articles, master's, and doctoral theses published between 1999-2020 in national and international databases were scanned. As a result of the literature review, it was deemed appropriate to include a total of 100 studies in the meta-analysis. In the meta-analysis study, subgroup analysis was performed in the fields of science, publication year, education levels, sample size, application period and publication types. As a result of the meta-analysis, it was determined that student-centered practices had a positive effect on students' SPS in science lessons compared to teacher-centered ones. It was also found out that 93 of the 100 studies included in the study had a positive effect size and 7 had a negative effect size value. Of the positive studies, 6 were at the level of weak effect, 23 at the level of small effect, 21 at the level of medium effect, and 43 at the level of large effect. In light of the findings obtained, student-centered practices in science education appear to have a stronger effect on developing students' scientific process skills than teacher-centered practices.

Introduction

The aim of science education is to develop students' problem-solving skills, evaluation of knowledge and logical reasoning skills to reach higher cognitive skills (Glaze, 2018). Considering the developments in technology in the 21st century, individuals' access to information becomes much easier and as a result, individuals are expected to be more productive (Topçu & Çiftçi, 2018). In this context, changes are made in science programs by taking into account the developments and changes in science. Scientific and technological developments both cause differences in the needs of individuals and also necessitate changes

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in learning and teaching approaches. With the change in learning and teaching approaches; it is aimed to raise individuals who can produce knowledge and use this information actively. In this context, individuals are expected to have high characteristics such as critical approach to problems, communication skills and entrepreneurship. In the curricula that are updated to raise individuals with these characteristics, the aim is to transfer knowledge and enable individuals to acquire values and skills by considering individual factors. The field-specific skills part of the curriculum which is in use in Turkey to reach these goals mentions Scientific Process Skills (SPS), life skills, engineering, and design skills (T.R. Ministry of National Education Board of Education and Discipline [MoNE], 2018).

SPS have been recognized by Science-A Process Approach – SAPA curriculum Project developed through the American Association for the Advancement of Science-AAAS. SPS includes adaptation to different disciplines and also skills that can be transferred to other fields, which are desired behaviors in a scientist (Mutlu, 2012). In the science lesson education program, which was last updated in 2018 (MoNE, 2018), SPS includes the skills that scientists use in their studies such as making observations, measuring, classifying, recording data, forming hypotheses, using data, creating models, making inferences, changing, and controlling variables, and experimenting (Köksal, Koray, & Açıkgül-Fırat, 2020). These skills can be defined as the ability to establish complex and organized thinking and/or action schemes to achieve an objective (Tavares, Vieira, & Pedro, 2017).

The fact that SPS has been included in the secondary science education curriculum applied in Turkey since 2005 has caused an increase in the number of studies conducted in this field. Considering that studies on SPS started about 60 years ago in developed countries, it can be said that there are a large number of studies conducted on the field. It is possible to compare the results of many of these studies conducted independently in different countries, with varying levels of education and subject areas. It means that the results of many studies can be generalized and provide a general tendency to shed light on new studies. It is only possible for researchers to provide clarity for a new study with the results obtained from research synthesis. Meta-analysis is a synthesis of individual studies on the same research topic, can be used to achieve these goals (Şad, Kış, Demir, & Özer, 2016).

Meta-Analysis

In general, meta-analysis can be defined as a characteristic analysis of the result statistics of the quantities of effect sizes (such as correlation coefficients or p values) in studies conducted in different ways (Lipsey and Wilson, 2001). The aims of meta-analysis can be explained as increasing the sample size by bringing together studies with small sample sizes, improving effect size estimations by increasing statistical power, and generalizing the findings by combining them (Büyüköztürk et al., 2014), to evaluate the inconsistencies in different sources, and examining the reasons of these (Kavale, 2001) and to reveal new research topics that can be examined in line with the data obtained (Franke, 2001). Steps planned meticulously should be followed within a specific system to achieve these goals. The steps followed in meta-analyses are briefly as follows (Bakioğlu and Özcan, 2016):

- Choosing the subject area to be researched,
- Putting forward the hypotheses relating to the subject,
- Establishing the inclusion and exclusion criteria of the study,
- Collecting the data from studies that meet the requirements and transforming the results into a standard form,

- Bringing together the results of the study with suitable methods,
- Reporting the analysis results.

Screening Studies for SPS in Science Education

When the literature was reviewed, it was found that the study of meta-analysis, in which SPS is discussed directly in the field of science, is almost nonexistent. In this sense, it is expected that this research will contribute to the literature. Because, knowing the common results and effect levels of these studies will make an important contribution to the structuring of new studies, together with the fact that SPS, one of the most basic skills and concepts of science education, has been discussed in many studies. When the literature is scanned, it has been determined that the number of studies on SPS by researchers who take into account the field-specific skills included in the science curriculum is quite high, but the number of studies on meta-analysis is limited. For example, in their study in which they researched the effects of research and inquiry-based learning approach on students' SPS when compared with conventional teaching method, Miranti, Abdurrahman and Ertikanto (2018) conducted a meta-analysis of 15 experimental studies. According to the average effect size of this study, it was found that the relevant approach had a moderate level of effect on SPS. Ramdhayani, Purwoko, and Muntari (2019) conducted a meta-analysis of a total of 12 national journal articles in their study in which they examined the effect of the project-based learning model on students' SPS compared to the traditional teaching method. According to the average effect size of these 12 studies, it has been determined that the relevant approach has a moderate effect on SPS. Aktamış, Hiğde, and Özden (2016) conducted a meta-analysis by considering 3 articles and 8 thesis studies in their studies, in which they examined the effect of students on SPS by using inquiry-based learning method. According to the average effect size of these 11 studies, it has been determined that the relevant approach has a moderate effect on SPS. Kozcu Çakır (2017) examined the effect of the 5E learning model on students' SPS compared to the traditional teaching method, and 5 articles and 1 thesis were included in the meta-analysis. According to the results of the 6 studies analyzed, it was determined that the 5E learning model had a very large effect on improving students' SPS. In a study conducted by Alemli (2019), the effects of research and inquiry-based learning approach on academic achievement, conceptual understanding, attitude and SPS were discussed. Only in 6 of the 36 studies analyzed, average effect size was found by including SPS effect size in the analysis. As a result of the study, a low significant difference was found in terms of SPS in favour of experimental group students. Karakuş and Yalçın (2016) examined the effects of argumentation-based learning in science education on academic achievement and SPS. According to the results of the 15 studies analyzed, it was found that argumentation-based learning in science education had a large effect on developing students' SPS. While differences in such studies were generally in favour of experimental group, it has been found that effect sizes of studies were significantly different from each other. These differences in the results may be due to the limited number of meta-analyses on SPS, as well as the small number of studies that were included in the meta-analyses. Therefore, the fact that there are few meta-analyses and also these analyses have not been conducted with large samples was effective in conducting this study because the selected sample may not always represent the population accurately. In this context, by conducting a larger study on SPS, the number of studies and also study sample will increase and thus it will be possible to increase the level of significance, which is very important in quantitative studies.

The teacher-centered approach processes a process in which the teacher transfers the available information, and the student is the passive recipient of the information. In this process,

individuals are growing up lacking skills such as creative thinking, analytical thinking and problem-solving skills (Açıkgöz, 2002). In the student-centered approach, it is ensured that the individual is actively involved in the learning process by supporting the individual in developing responsibility and the ability to access information (Elen et al., 2007). The large number of studies examining the effects of student and teacher centred approaches on SPS, which have been conducted on student groups studying different subject areas of science in Turkey and other countries, has created the need to conduct a meta-analysis of these studies. The cumulative increase in the number of studies has brought along differences in results. This situation has necessitated the gathering, analysis, and interpretation of study data because in studies conducted, there are a lot of differences such as the level of education and number of students included in the study, the duration of experimental practices and subjects discussed. Even if studies are mostly carried out independently, it has been emphasized in many studies that more research should be done on the subject discussed. However, it is clearly revealed that there is a need for comprehensive and highly reliable studies in order to interpret the knowledge gained with a holistic perspective by making differences in studies and to provide a guide for researchers who will conduct future studies (Akgöz, Ercan, and Kan, 2004). For this reason, it was decided to conduct this meta-analysis to provide a more precise judgment about the effects of student and teacher centred approaches applied in science lesson on students' PSP and to make more effective assumptions for the future.

In this context, the study aims to conduct a meta-analysis to examine the experimental studies in which teacher and student-centred approaches were used between 1999 and 2020 and show the effect size of students on SPS. Sub-problems of the study are as follows:

Do the effects of teacher and student-centered approaches on students' SPS differ in terms of:

(1) Type of the study,
(2) The year of application,
(3) Application period,
(4) Level of education,
(5) Sample size, and
(6) Publication type as national-international

Method

This research was carried out using the meta-analysis method. Meta-analysis is the process of making use of statistical methods to bring together the results of studies conducted independently on the same subject and to make sense of the difference between these studies, and to get more reliable and more sensitive results by enlarging study groups (Dempfle, 2006; Littel, Corcoran, and Pillai, 2008; Petitti, 2000). In this method, the investigated studies' results are converted into a standard unit of measurement, and the results are evaluated according to effect sizes by comparing with statistical procedures. As a result, it shows the effect level of a selected application on the chosen dependent variable. Effect size results obtained from the analysis determine the tendencies in the field and guide future studies in the planning process (Balemen, 2016).

Data Collection

The studies examined within this study's scope include national and international master's, doctoral theses, and articles published in peer-reviewed journals. To access the

master's and doctoral theses published in Turkey, the research was carried out using the keyword SPS, the study's dependent variable, found on the Higher Education Board's website (YÖK) National Theses Screening Centre. In this scan, 492 theses were reached. They were examined in terms of their suitability for meta-analysis. Then 434 of them were not included in this meta-analysis due to their field of study, study subject, and the study group was not suitable. Thus, 56 master's and doctoral theses were included in the meta-analysis. Of the master's theses in this study, since 4 had 2 experimental and 1 control group and 1 had 3 experimental and 1 control group, they were included in the analysis as different studies. Similarly, since 3 of the doctoral theses had 2 experimental and 1 control group, each were included in the analysis as a separate study. When there is more than one control group and the experimental group in Solomon designs or factorial designs, each comparison is processed as a different data (Ekemen, 2019).

The articles of researchers in Turkey published in national and international journals were accessed using Google Scholar and ULAKBİM Social Sciences Database. At the end of this review, 56 studies were reached; some of them were not included in the scope of the research because it was determined that there was no experimental and control group and some of them were missing data. A total of 13 articles published in journals were analyzed by including them in national publications at the end of these scans. Since two different units were discussed in one of these articles and 2 experimental and 1 control groups were used for each unit, they were coded as separate studies in this study. ProQuest Dissertations and Thesis Global, Educational Resources Information Center (ERIC), Ebsco, Base, Bioone, DOAJ and Semantic Scholar databases were used to access international articles and theses. At the end of these scans, a total of 17 articles and 12 doctoral theses published in international journals were included in this research as international publications. This number is limited to studies whose full text has been reached from the relevant databases at the end of the scans. The search criteria for the studies are also presented in detail in the text. Of these 17 articles, since 2 had 2 different methods and used 2 experimental and 1 control group and since another article had 3 experimental and 1 control group, these studies were included in the analysis as separate studies. The studies published in international journals by researchers in Turkey and abroad were taken in the category of international studies in terms of type of publication, while others were included in the category of national studies. As a result, the data of 100 studies, which used SPS variable, included data suitable data for meta-analysis and were published as postgraduate thesis or scientific articles, were analyzed. The following figure shows the basic procedures regarding the steps of the study:

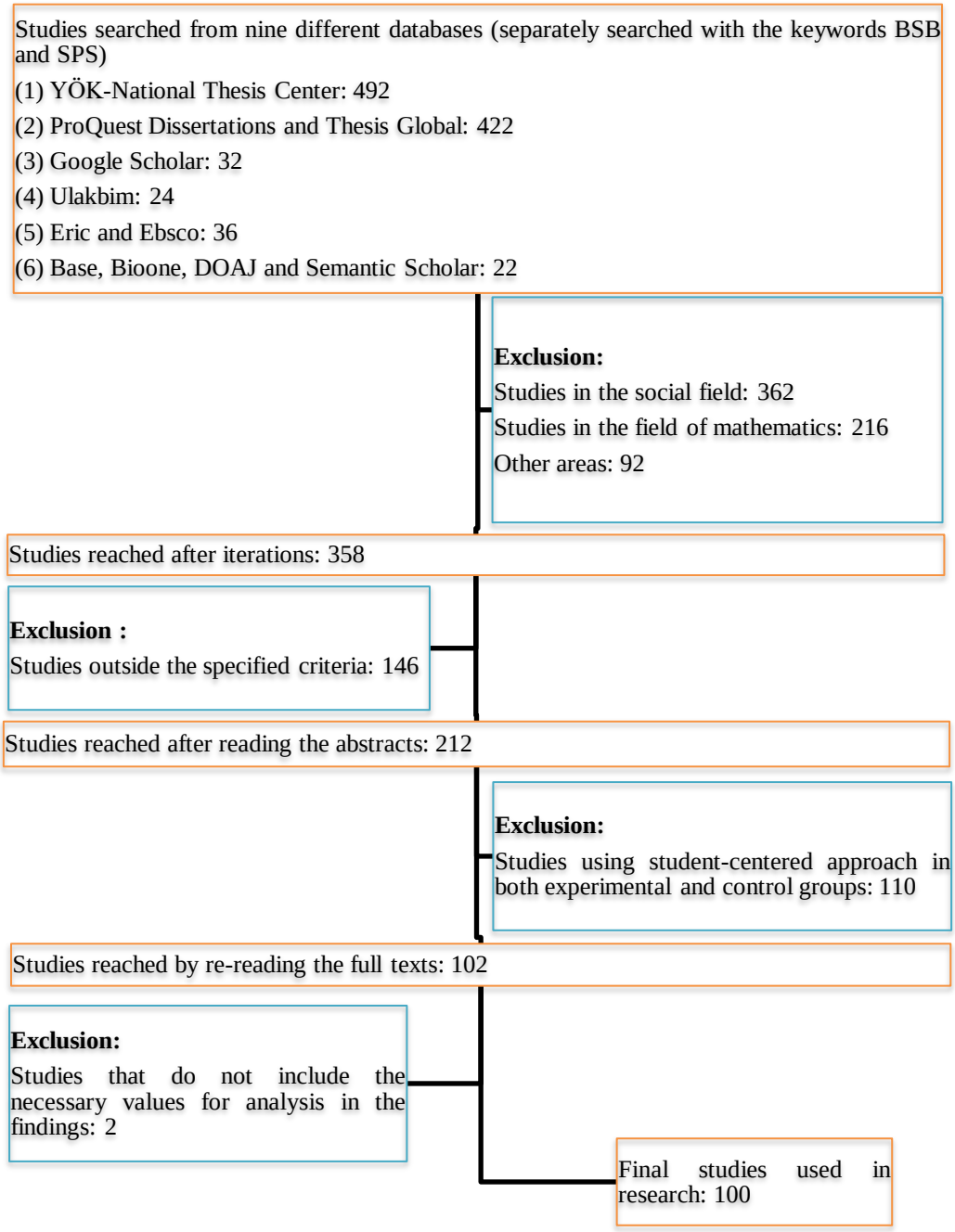


Figure 1. Flowchart of the Study

Analysis Characteristics

The fact that the inclusion criteria are too broad may reduce the reliability as a result of weakening the quality of the studies to be obtained. The fact that the criteria are too narrow may cause the results to be obtained based on a limited number of studies and generalizations cannot be made (Lam and Kenedy, 2005). For this reason, in addition to taking care that the inclusion criteria were not too narrow or too broad, it was aimed to conduct the study based on current studies. Below are the criteria looked for in the studies included in the meta-analysis:

- The studies were published between 1999 and 2020,
- Having been conducted in one of the fields of science (physics, chemistry or biology courses),
- The study has been published in Turkish or English (abstract and data),
- The studies are master thesis, doctoral thesis or research article published in scientific refereed journals,
- BSB scores being the dependent variable of the research,
- Studies are designed according to a full experimental or quasi-experimental design,
- One of the current/alternative learning approaches in the experimental group; in the control group, one of the traditionally accepted or presentation-based teaching approaches was used,
- In the findings, the values needed for meta-analysis such as arithmetic mean, standard deviation, number of students, and t-value related to the SPS tests of the experimental and control groups are included.

Data Coding

A coding form suitable for the study was prepared to determine whether the studies recorded for SPS, which was the dependent variable and keyword of the study, complied with the inclusion criteria of the research and to compare the included ones with each other. The coding form consisted of three parts. The first part included the name of the study, year of the study, and type of the study in order to specify the identity of the study; the second part included the level of education and experimental study durations to identify the content of the study; the third part included statistical data of the experimental and control groups such as pre-test and post-test arithmetic mean, standard deviation and sample size. To determine the rater reliability for the data to be analysed, the codes were entered separately in the data coding form by two researchers who were experts in science teaching. While one of these researchers is continuing doctorate studies in science teaching, the other researcher is working as a faculty member in the related field. While determining the data's consistency, Miles and Huberman's (1994) formula for percentage of agreement was used. According to this formula, the agreement level of the codes given by the researchers was found as 96%. Considering that the rater reliability is ensured if the agreement exceeds 70% between the coding (Yıldırım & Şimşek, 2011), it was decided that the reliability level of the coded data was appropriate to start the meta-analysis.

Variables of the Study

- *Dependent Variable:* The dependent variable of the study is the students' SPS scores in lessons related to science.
- *Independent Variables*: The study's primary independent variable is active/student-centred learning approaches and traditionally accepted or presentation-based/teacher-centered methods/approaches applied in experimental and control groups. The other independent variables of the study are the type of research, years of application, duration of application, education level of students (primary school, secondary school, high school, and university), sample sizes of the experimental study, and types of national-international publications.

Data Analysis

Since the arithmetic means of the SPS levels of the participants in studies included in the meta-analysis were obtained with different scales, and an analysis was made by using the study effect method due to group differences (Lipsey & Wilson, 2001). With the study effect method, a "d" value called effect size is found by processing the difference between the experimental and control groups' SPS scores. While obtaining the effect size, standard deviation, arithmetic mean, F, t, or r value of studies carried out independently are converted with the "d=($\overline{X}$- $\overline{X}$c)/SD" formula (Glass, 1976). If the effect size value is negative, it means that the control group has a high mean score; if it is positive, it means that the experimental group has a high mean score (Özdemirli, 2011). Cohen' d values examined in this study; It is the data obtained as a result of dividing the difference ($\overline{X}$) between the mean BSB scores of the experimental and control groups by the combined standard deviation (SD) value (Glass, 1976). Cohen's (1988, p. 40) effect size classification is given below:

- .20-.50 small,
- .50-.80 moderate,
- .80 and + large.

Since each study's effect size value may be different during the analysis phase, it is calculated separately, and a heterogeneity test is conducted to explain this difference in the values. In this study, since there was only 2 study at the primary school level, the effect size value was calculated by combining the research with studies at the secondary school level. Primary education expression was used for the data in these two groups. Chi-square homogeneity test (Q statistic) is used to determine the heterogeneity between the studies used in the research. The result of heterogeneity is used to decide for the model to be used while calculating the overall effect. In the heterogeneity test, p-value and Q value are found. To determine whether the study is heterogeneous or not, p-value should be smaller than the .05 significance value or the Q value should be smaller than the value corresponding to the degree of freedom in the chi-square table. If the study result is decided to be heterogeneous, the data analysis is done according to Random Effects Model (REM). In order for the meta-analysis result to be homogeneous and the Fixed Effects Model (SEM) to be used, the p value should not be less than .05 significance value or the Q value should not be less than the value in the chi-square table (Field, 2001). For this reason, a computer package program was used in the creation of tables, graphics and figures with analysis.

Results regarding the general effect size

Before starting to calculate the effect sizes of studies on BSB, it should be decided which meta-analysis model will be used. For this purpose, the homogeneity/heterogeneity of the studies in which SEM and REM and SPS tests were applied for the data included in the study were tested. The results of these procedures are shown in Table 1.

Table 1. Findings Related to Effect Sizes of Studies on Fixed Effects and Random Effects Model

	Mean effect size (ES)	Degree of freedom (df)	I^2	Level of homogeneity (Q)	Standard error (Se)	95% Confidence interval for ES	
						Lower limit	Upper limit
FEM	.60	99	87.96	821.95	.02	.56	.65
REM	.74				.07	.60	.87

When the studies were analysed, the mean effect size value was found as .60 according to FEM and as .74 according to REM. As a result of the homogeneity test, conducted to examine the homogeneity of the effect sizes of studies included in the study, Q statistical value was found as 821.95. Heterogeneity test Q statistical value was between 113.15 and 124.34 values which correspond to df=99 at 95% confidence interval in $\chi 2$ critical values table. The result that Q=821.95 value was much higher than this value shows that the research data were heterogeneous. According to these data, the effect sizes of the studies included in the study are heterogeneous. Since the research was significant according to heterogeneity test results, REM was used (Dinçer, 2014). This result shows that the analysis of the studies in the meta-analysis should be made according to REM.

The analyses conducted by REM show that the upper limit of 95% confidence interval was .87, while the lower limit was .60, and the mean effect size was .74. This value indicates that the studies' effect sizes included in the meta-analysis are homogeneous according to REM. The distribution of the effect sizes of all studies included in the meta-analysis is shown in Table 2.

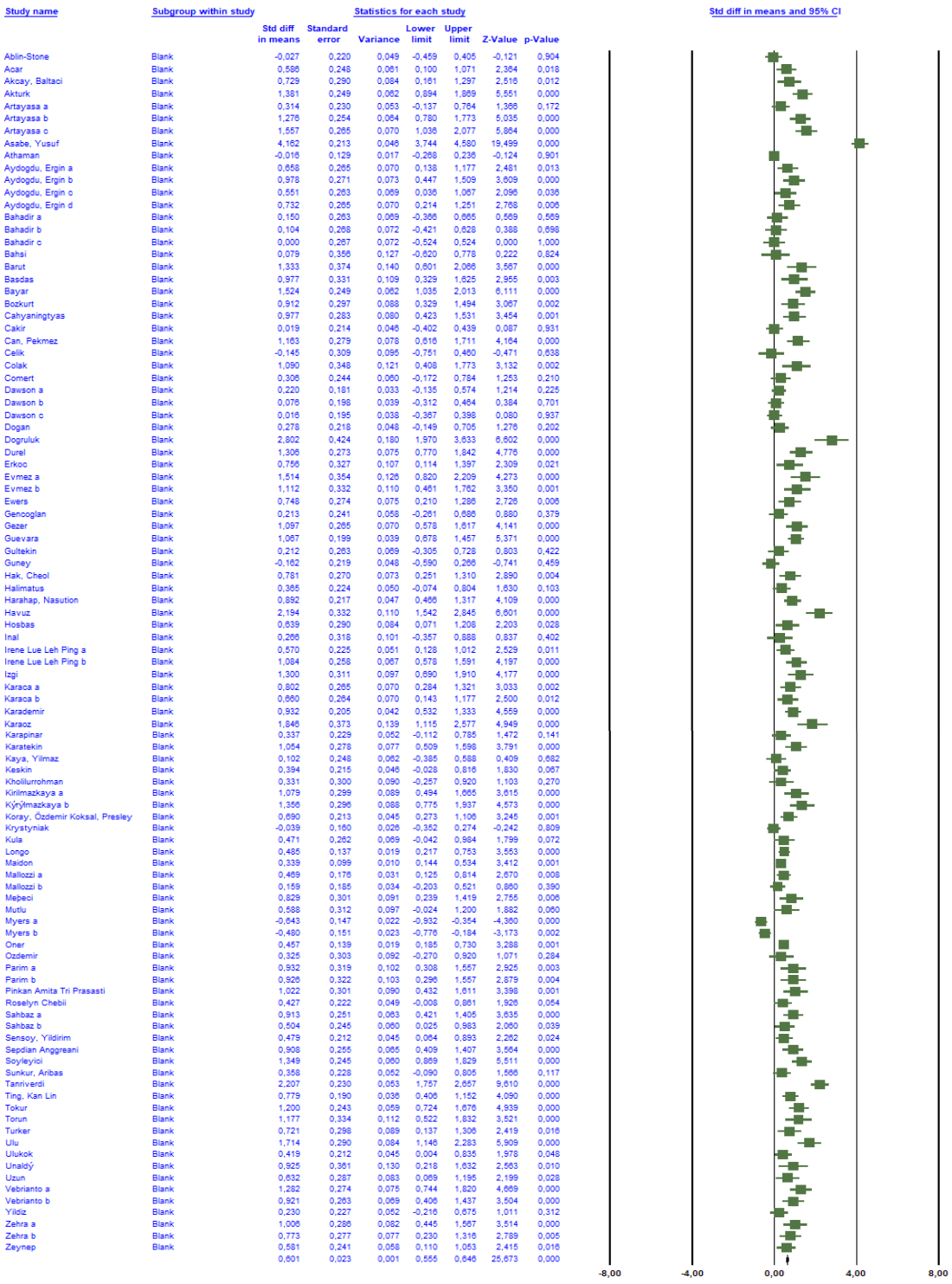
Table 2. Distribution of Effect Size Values of Studies

No	ES	Se	S^2	p	No	ES	Se	S^2	p
1	-.64	.15	.02	.	**51**	.73	.29	.08	.01
2	-.48	.15	.02	.	**52**	.73	.27	.07	.01
3	-.16	.22	.05	.46	**53**	.75	.27	.08	.01
4	-.15	.31	.10	.64	**54**	.76	.33	.11	.02
5	-.04	.16	.03	.81	**55**	.77	.28	.08	.01
6	-.03	.22	.05	.90	**56**	.78	.19	.04	.
7	-.02	.13	.02	.90	**57**	.78	.21	.07	.
8	.	.27	.07	1.00	**58**	.80	.27	.07	.
9	.02	.20	.04	.94	**59**	.83	.30	.09	.01
10	.02	.21	.05	.93	**60**	.89	.22	.05	.
11	.08	.20	.04	.70	**61**	.91	.26	.07	.
12	.08	.36	.13	.82	**62**	.91	.30	.09	.
13	.10	.25	.06	.68	**63**	.91	.25	.06	.
14	.10	.27	.07	.70	**64**	.92	.26	.07	.
15	.15	.26	.07	.57	**65**	.93	.36	.13	.01
16	.16	.19	.03	.39	**66**	.93	.32	.10	.
17	.21	.26	.07	.42	**67**	.93	.32	.10	.
18	.21	.24	.06	.38	**68**	.93	.21	.04	.
19	.22	.18	.03	.23	**69**	.98	.28	.08	.
20	.23	.23	.05	.31	**70**	.98	.33	.11	.
21	.27	.32	.10	.40	**71**	.98	.27	.07	.
22	.28	.22	.05	.20	**72**	1.01	.29	.08	.
23	.31	.24	.06	.21	**73**	1.02	.30	.09	.
24	.31	.23	.05	.17	**74**	1.05	.28	.08	.
25	.33	.30	.09	.28	**75**	1.07	.20	.04	.
26	.33	.30	.09	.27	**76**	1.08	.30	.09	.
27	.34	.23	.05	.14	**77**	1.08	.26	.07	.
28	.34	.10	.01	.	**78**	1.09	.35	.12	.
29	.36	.23	.05	.12	**79**	1.10	.27	.07	.
30	.37	.22	.05	.10	**80**	1.11	.33	.11	.
31	.39	.22	.05	.07	**81**	1.16	.28	.08	.
32	.42	.21	.05	.05	**82**	1.18	.33	.11	.
33	.43	.22	.05	.05	**83**	1.20	.24	.06	.
34	.46	.14	.02	.	**84**	1.28	.25	.06	.
35	.47	.18	.03	.01	**85**	1.28	.27	.08	.
36	.47	.26	.07	.07	**86**	1.30	.31	.10	.
37	.48	.21	.05	.02	**87**	1.31	.27	.08	.
38	.49	.14	.02	.	**88**	1.33	.37	.14	.
39	.50	.25	.06	.04	**89**	1.35	.25	.06	.
40	.55	.26	.07	.04	**90**	1.36	.30	.09	.
41	.57	.23	.05	.01	**91**	1.38	.25	.06	.
42	.58	.24	.06	.02	**92**	1.51	.35	.13	.
43	.59	.25	.06	.02	**93**	1.52	.25	.06	.
44	.59	.31	.10	.06	**94**	1.56	.27	.07	.
45	.63	.29	.08	.03	**95**	1.71	.29	.08	.
46	.64	.29	.09	.03	**96**	1.85	.37	.14	.
47	.66	.27	.07	.01	**97**	2.19	.33	.11	.
48	.66	.26	.07	.01	**98**	2.21	.23	.05	.
49	.69	.21	.05	.	**99**	2.80	.42	.18	.
50	.72	.30	.09	.02	**100**	4.16	.21	.05	.

Note: ES: Mean effect size, Se: Standard error, S2: Variance, p: Significance value.

Considering Table 2, it was determined that the smallest effect size value was -.64, the highest effect size value was 4.16, and its range was very close to the maximum score (4.80). In addition to this, it was found that a great majority of the studies' effect size values ranged between .00 and 1.00. It was found that the effect sizes of eight studies were smaller than .00,

while the effect sizes of four studies were greater than 2.00. Figure 2 includes the graph showing the effect size values for students' SPS scores:



Study name	Subgroup within study	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Ablin-Stone	Blank	-0,027	0,220	0,049	-0,459	0,405	-0,121	0,904
Acar	Blank	0,586	0,248	0,061	0,100	1,071	2,364	0,018
Akcay, Baltaci	Blank	0,729	0,290	0,084	0,161	1,297	2,516	0,012
Akturk	Blank	1,381	0,249	0,062	0,894	1,869	5,551	0,000
Artayasa a	Blank	0,314	0,230	0,053	-0,137	0,764	1,366	0,172
Artayasa b	Blank	1,276	0,254	0,064	0,780	1,773	5,035	0,000
Artayasa c	Blank	1,557	0,265	0,070	1,036	2,077	5,864	0,000
Asabe, Yusuf	Blank	4,162	0,213	0,046	3,744	4,580	19,499	0,000
Atharian	Blank	-0,016	0,129	0,017	-0,268	0,236	-0,124	0,901
Aydogdu, Ergin a	Blank	0,658	0,265	0,070	0,138	1,177	2,481	0,013
Aydogdu, Ergin b	Blank	0,978	0,271	0,073	0,447	1,509	3,609	0,000
Aydogdu, Ergin c	Blank	0,551	0,263	0,069	0,036	1,067	2,096	0,036
Aydogdu, Ergin d	Blank	0,732	0,265	0,070	0,214	1,251	2,768	0,006
Bahadir a	Blank	0,150	0,263	0,069	-0,366	0,665	0,569	0,569
Bahadir b	Blank	0,104	0,268	0,072	-0,421	0,628	0,388	0,698
Bahadir c	Blank	0,000	0,267	0,072	-0,524	0,524	0,000	1,000
Bahsi	Blank	0,079	0,356	0,127	-0,620	0,778	0,222	0,824
Barut	Blank	1,333	0,374	0,140	0,601	2,066	3,567	0,000
Basdas	Blank	0,977	0,331	0,109	0,329	1,625	2,955	0,003
Bayar	Blank	1,524	0,249	0,062	1,035	2,013	6,111	0,000
Bozkurt	Blank	0,912	0,297	0,088	0,329	1,494	3,067	0,002
Cahyaningtyas	Blank	0,977	0,283	0,080	0,423	1,531	3,454	0,001
Cakir	Blank	0,019	0,214	0,046	-0,402	0,439	0,087	0,931
Can, Pekmez	Blank	1,163	0,279	0,078	0,616	1,711	4,164	0,000
Celik	Blank	-0,145	0,309	0,095	-0,751	0,460	-0,471	0,638
Colak	Blank	1,090	0,348	0,121	0,408	1,773	3,132	0,002
Comert	Blank	0,306	0,244	0,060	-0,172	0,784	1,253	0,210
Dawson a	Blank	0,220	0,181	0,033	-0,135	0,574	1,214	0,225
Dawson b	Blank	0,076	0,198	0,039	-0,312	0,464	0,384	0,701
Dawson c	Blank	0,018	0,195	0,038	-0,367	0,398	0,080	0,937
Dogan	Blank	0,278	0,218	0,048	-0,149	0,705	1,276	0,202
Dogruluk	Blank	2,802	0,424	0,180	1,970	3,633	6,602	0,000
Durel	Blank	1,306	0,273	0,075	0,770	1,842	4,776	0,000
Erkoc	Blank	0,766	0,327	0,107	0,114	1,397	2,309	0,021
Evmez a	Blank	1,514	0,354	0,126	0,820	2,209	4,273	0,000
Evmez b	Blank	1,112	0,332	0,110	0,461	1,762	3,350	0,001
Ewers	Blank	0,748	0,274	0,075	0,210	1,286	2,726	0,006
Gencoglan	Blank	0,213	0,241	0,058	-0,261	0,686	0,880	0,379
Gezer	Blank	1,097	0,265	0,070	0,578	1,617	4,141	0,000
Guevara	Blank	1,067	0,199	0,039	0,678	1,457	5,371	0,000
Gultekin	Blank	0,212	0,263	0,069	-0,305	0,728	0,803	0,422
Guney	Blank	-0,162	0,219	0,048	-0,590	0,266	-0,741	0,459
Hak, Cheol	Blank	0,781	0,270	0,073	0,251	1,310	2,890	0,004
Halimatus	Blank	0,365	0,224	0,050	-0,074	0,804	1,630	0,103
Harahap, Nasution	Blank	0,892	0,217	0,047	0,466	1,317	4,109	0,000
Havuz	Blank	2,194	0,332	0,110	1,542	2,845	6,601	0,000
Hosbas	Blank	0,639	0,290	0,084	0,071	1,208	2,203	0,028
Inal	Blank	0,266	0,318	0,101	-0,357	0,888	0,837	0,402
Irene Lue Leh Ping a	Blank	0,570	0,225	0,051	0,128	1,012	2,529	0,011
Irene Lue Leh Ping b	Blank	1,084	0,258	0,067	0,578	1,591	4,197	0,000
Izgi	Blank	1,300	0,311	0,097	0,690	1,910	4,177	0,000
Karaca a	Blank	0,802	0,265	0,070	0,284	1,321	3,033	0,002
Karaca b	Blank	0,660	0,264	0,070	0,143	1,177	2,500	0,012
Karademir	Blank	0,932	0,205	0,042	0,532	1,333	4,559	0,000
Karaoz	Blank	1,846	0,373	0,139	1,115	2,577	4,949	0,000
Karapinar	Blank	0,337	0,229	0,052	-0,112	0,785	1,472	0,141
Karatekin	Blank	1,054	0,278	0,077	0,509	1,598	3,791	0,000
Kaya, Yilmaz	Blank	0,102	0,248	0,062	-0,385	0,588	0,409	0,682
Keskin	Blank	0,394	0,215	0,046	-0,028	0,816	1,830	0,067
Kholilurrohman	Blank	0,331	0,300	0,090	-0,257	0,920	1,103	0,270
Kirilmazkaya a	Blank	1,079	0,299	0,089	0,494	1,665	3,615	0,000
Kýrýlmazkaya b	Blank	1,356	0,296	0,088	0,775	1,937	4,573	0,000
Koray, Özdemir Koksal, Presley	Blank	0,690	0,213	0,045	0,273	1,106	3,245	0,001
Krystyniak	Blank	-0,039	0,160	0,026	-0,352	0,274	-0,242	0,809
Kula	Blank	0,471	0,262	0,069	-0,042	0,984	1,799	0,072
Longo	Blank	0,485	0,137	0,019	0,217	0,753	3,553	0,000
Maidon	Blank	0,339	0,099	0,010	0,144	0,534	3,412	0,001
Mallozzi a	Blank	0,469	0,176	0,031	0,125	0,814	2,670	0,008
Mallozzi b	Blank	0,159	0,185	0,034	-0,203	0,521	0,860	0,390
Meþeci	Blank	0,829	0,301	0,091	0,239	1,419	2,755	0,006
Mutlu	Blank	0,588	0,312	0,097	-0,024	1,200	1,882	0,060
Myers a	Blank	-0,643	0,147	0,022	-0,932	-0,354	-4,360	0,000
Myers b	Blank	-0,480	0,151	0,023	-0,776	-0,184	-3,173	0,002
Oner	Blank	0,457	0,139	0,019	0,185	0,730	3,288	0,001
Ozdemir	Blank	0,325	0,303	0,092	-0,270	0,920	1,071	0,284
Parim a	Blank	0,932	0,319	0,102	0,308	1,557	2,925	0,003
Parim b	Blank	0,926	0,322	0,103	0,296	1,557	2,879	0,004
Pinkan Amita Tri Prasasti	Blank	1,022	0,301	0,090	0,432	1,611	3,398	0,001
Roselyn Chebii	Blank	0,427	0,222	0,049	-0,008	0,861	1,926	0,054
Sahbaz a	Blank	0,913	0,251	0,063	0,421	1,405	3,635	0,000
Sahbaz b	Blank	0,504	0,245	0,060	0,025	0,983	2,060	0,039
Sensoy, Yildirim	Blank	0,479	0,212	0,045	0,064	0,893	2,262	0,024
Sepdian Anggreani	Blank	0,908	0,255	0,065	0,409	1,407	3,564	0,000
Soyleyici	Blank	1,349	0,245	0,060	0,869	1,829	5,511	0,000
Sunkur, Aribas	Blank	0,358	0,228	0,052	-0,090	0,805	1,566	0,117
Taniriverdi	Blank	2,207	0,230	0,053	1,757	2,657	9,610	0,000
Ting, Kan Lin	Blank	0,775	0,190	0,036	0,406	1,152	4,090	0,000
Tokur	Blank	1,200	0,243	0,059	0,724	1,676	4,939	0,000
Torun	Blank	1,177	0,334	0,112	0,522	1,832	3,521	0,000
Turker	Blank	0,721	0,298	0,089	0,137	1,306	2,419	0,016
Ulu	Blank	1,714	0,290	0,084	1,146	2,283	5,909	0,000
Ulukok	Blank	0,419	0,212	0,045	0,004	0,835	1,978	0,048
Unaldý	Blank	0,925	0,361	0,130	0,218	1,632	2,563	0,010
Uzun	Blank	0,632	0,287	0,083	0,069	1,195	2,199	0,028
Vebrianto a	Blank	1,282	0,274	0,075	0,744	1,820	4,669	0,000
Vebrianto b	Blank	0,921	0,263	0,069	0,406	1,437	3,504	0,000
Yildiz	Blank	0,230	0,227	0,052	-0,216	0,675	1,011	0,312
Zehra a	Blank	1,006	0,286	0,082	0,445	1,567	3,514	0,000
Zehra b	Blank	0,773	0,277	0,077	0,230	1,316	2,789	0,005
Zeynep	Blank	0,581	0,241	0,058	0,110	1,053	2,415	0,016
		0,601	0,023	0,001	0,555	0,646	25,673	0,000

Figure 2. Forest Plot Showing the Distribution of Effect Size Values of Studies

According to the graph, the lowest effect size – .64 by Myers (2004); the highest effect size with 4.16 was found in the studies conducted by Asabe & Yusuf (2013). While only seven of the 100 studies included in the study had negative effect sizes, ninety-three had positive effect sizes. The following figure shows the normal distribution table of the studies examined in the study.

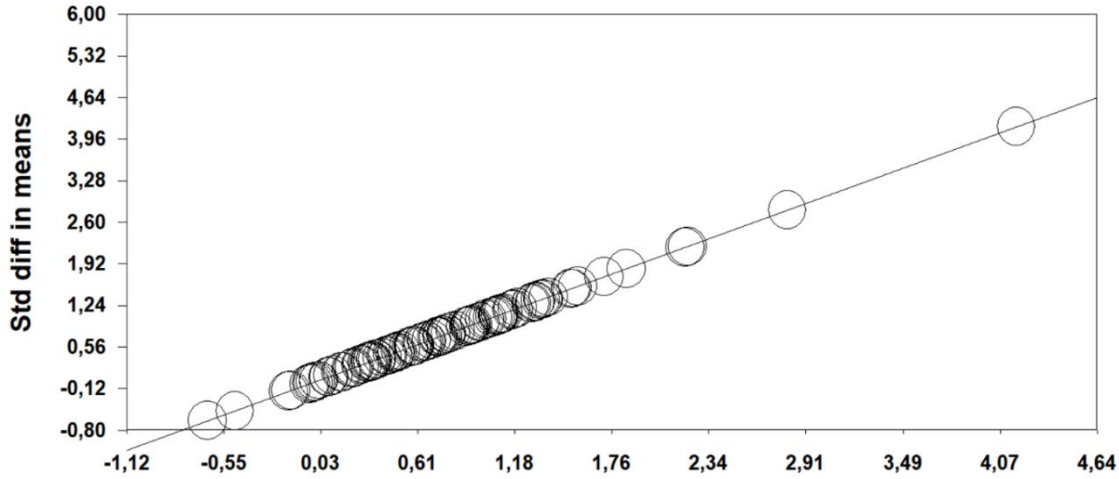


Figure 3. Normal Distribution Graph of Effect Sizes

According to the graph, it was found that the effect size values of the studies included in the analysis were mostly around the normal distribution line. It shows that the studies were normally distributed. The most important problem that threatens the validity of the meta-analysis process is stated as publication bias. While the funnel plot is often considered the best tool to use in detecting publication bias, the forest plot also provides a visual summary of the datasets (Sterne, Becker, & Egger, 2005). The figure below is the funnel graph showing the distribution of effect sizes of studies included in the meta-analysis.

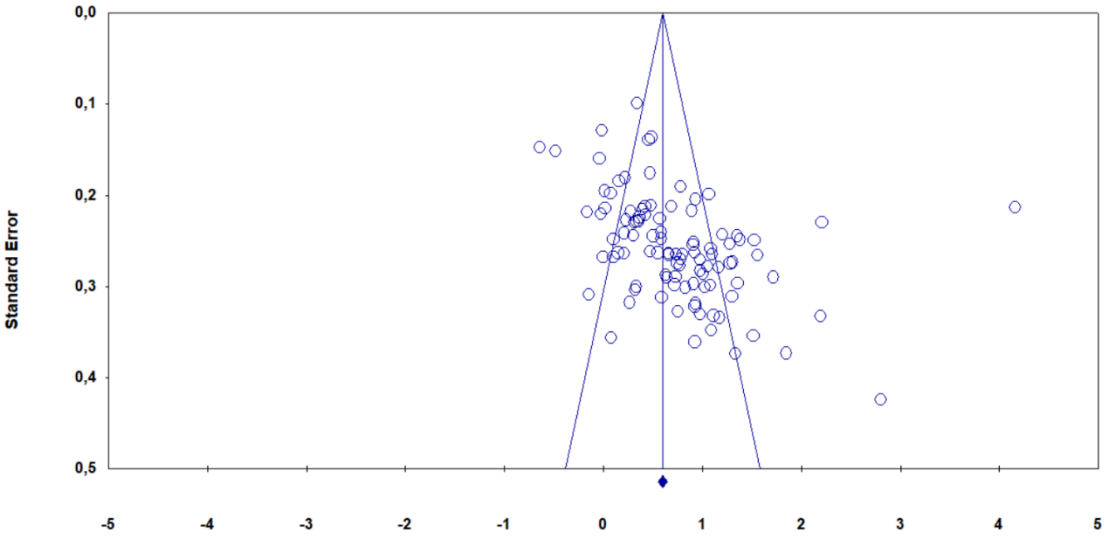


Figure 4. Funnel Graph of Effect Sizes

A skewed and asymmetrical distribution occurs in studies with publication bias. When the graph is examined, it can be seen that there isn't an uneven and asymmetrical distribution; in other words, it can be seen that the effect sizes of the studies concentrate within the funnel, and the studies outside the funnel are distributed evenly on both sides. Based on this result, it can be said that there is no publication bias in the study.

Results

This part includes the results of the data obtained by combining the research problems with the meta-analysis method.

Findings of effect sizes according to the independent variables examined in the study

The findings regarding whether effect sizes differ according to the type of studies are shown in Table 3.

Table 3. Effect Sizes of Studies According to Their Types

Variable	Q	p	ES	N	Se	ES (95% CI)	
						Lower limit	Upper limit
Study	10.71	.005					
Article			.88	32	.14	.60	1.15
Master			.82	43	.09	.64	1.00
Doctorate			.41	25	.11	.21	.62

Considering the publication types related to BSB, the chi-square table of the studies included in the study, the critical value for the two degrees of freedom of the 95% confidence interval was determined to be 5.99. The homogeneity value (Q) of the studies evaluated as three subgroups for the publication type is 10.71. Since the homogeneity value between the groups was greater than the critical value, it was determined that there was a statistically significant difference according to the publication types in which the studies were conducted. In the study, the articles with the highest effect size value of .88; it was determined that the lowest effect size value with .41 belongs to doctoral theses. As a result of the analysis, it was found that the effect size values of both articles and postgraduate theses were significantly higher than those of doctoral theses.

Table 4. Effect Sizes According to Publication Years of Studies

Variable	Q	p	ES	N	Se	ES (95% CI)	
						Lower limit	Upper limit
Year	4.14	.126					
2009 and before			.55	30	.11	.34	.75
2010-2014			.73	39	.08	.56	.89
2015 and beyond			.92	31	.16	.61	1.23

According to the findings in Table 4; according to the publication years of the experimental studies, the highest effect value belongs to the studies between the years 2015-2020 with .92. This is followed by studies between the years 2010-2014 with an effect value of .73. Studies with the lowest effect size value of .55 for the years of publication are the studies between the years 1999-2009. According to the 95% confidence interval in the chi-square table, the critical value for these studies was found to be 5.99. Since the homogeneity value (Q) between the groups, which was created by considering the working years, is lower than the critical value, it can be said that there is no statistically significant difference in terms of SPS according to the working years.

Table 5. Effect Sizes According to the Education Levels of the Studies

Variable	Q	p	ES	N	Se	ES (95% CI)	
						Lower limit	Upper limit
Level	2.03	.362					
Primary education			.70	61	.06	.58	.82
High school			.43	8	.27	-.10	.95
University			.86	31	.17	.54	1.19

When Table 5 is examined, it has been determined that the most studies on SSB have been

done at primary education level with 61 publications according to education level. This is followed by university-level studies with 31 publications. It is seen that the studies conducted at the high school level are limited to 8. In terms of the level of effect size, it is the highest of the studies conducted at the university level with .86; it was determined that it had the lowest effect with a value of .43 in high school levels. Considering the chi-square table, it is seen that the critical value in the 95% confidence interval is 5.99. As a result of the analyzes made for the education level, the homogeneity value (Q) between the groups was determined as 2.03. In this context, since the homogeneity value is less than the critical value, it can be said that there is no statistically significant difference in terms of SPS according to the education level.

Table 6. Effect Levels According to the Duration of the Study

Variable	Q	p	ES	N	Se	ES (95% CI)	
						Lower limit	Upper limit
Duration	5.59	.232					
0-4 weeks			.74	14	.12	.50	.97
5-8 weeks			.59	32	.12	.36	.81
9-12 weeks			.78	22	.11	.57	1.00
13 and + weeks			.60	21	.11	.39	.81
Unspecified			1.32	11	.35	.62	2.01

According to the findings in Table 6; According to the experimental study times, the highest effect value with 1.32 belongs to the studies whose application period is not specified. This is followed by studies with an effect value of .78 and a duration of application between 9 and 12 weeks. These are the studies with the lowest effect size value of .59 and lasting between 5 and 8 weeks. Considering the chi-square table, it is seen that the critical value in the 95% confidence interval is 9.48. As a result of the analyzes made for the application period, the homogeneity value (Q) between the groups was determined as 5.59. Since the homogeneity value is less than the critical value, there was no statistically significant difference in terms of BSB according to the application time.

Table 7. Effect Sizes According to the Number of Persons Conducted the Studies

Variable	Q	p	ES	N	Se	ES (95% CI)	
						Lower limit	Upper limit
Sample	2.98	.225					
30-54			.88	26	.10	.68	1.08
55-79			.78	42	.07	.64	.92
80 and +			.58	32	.14	.30	.86

According to Table 7, the highest rate among the 100 experimental studies in which SPS was measured belongs to the studies with 42 studies and 55-79 participants. This is followed by 32 studies and studies with 80 or more participants. The lowest rate was found in 26 studies including 30-54 participants. Among these studies, it was determined that the highest effect value was .88 and belonged to the studies with 30-54 participants. The lowest effect level was found in studies including 80 and more individuals with .58. According to these data, it can be said that the effect size shows a certain downward trend as the number of participants increases. When the confidence interval is accepted as 95%, the critical value is 5.99; Since the homogeneity value (Q) was determined as 2.98 among the groups formed according to the number of participants, it can be said that there is no significant difference.

Table 8. Effect Levels of Studies According to Study Type as National or International Publication

Variable	Q	p	ES	N	Se	ES (95% CI)	
						Lower limit	Upper limit
Study type	.85	.357					
National			.78	69	.07	.66	.91
International			.64	31	.15	.35	.92

When we look at the types of studies on BSB, 69 of the studies included in the analysis are national; It has been determined that 31 of them belong to international publications. The effect size of national studies was .78; The effect size value of international studies was determined to be .64. Considering the chi-square table, it is seen that the critical value in the 95% confidence interval is 3.84. The homogeneity value (Q) of the studies considered as two subgroups according to the types of studies is .85. In this context, since the homogeneity value is less than the critical value, it can be said that there is no statistically significant difference in terms of SPS according to the types of studies.

Discussion and Conclusion

This study analysed the results of experimental studies which were conducted to find out to what extent current/alternative learning approaches and conventional or presentation-based teaching methods/approaches on different subject areas of science affected SPS. As a result of the statistical data of 100 national and international studies, approaches in which students were active were used in the experimental group and methods/approaches in which teachers carried out presentation-based practices were used in the control group in these studies examined. The aim was to compare the analysis of subcategories in the study with the results of previously conducted studies on this subject. Average effect size of the 100 studies which met inclusion criteria was found as .74. In the study conducted by Aktamış, Hiğde, and Özden in 2016, the average effect size was .74; In the study conducted by Kozcu Çakır in 2017, the average effect size value was determined as 1.67, but since there was no moderator analysis in both studies, a comparison could not be made. In the study conducted by Ramdhayani, Purwoko, and Muntari in 2019, the average effect size was determined as .44, but it could not be discussed in detail because there was no moderator analysis in its content. In a meta-analysis by Miranti, Abdurrahman, and Ertikanto (2018) which included 15 studies, it was concluded that inquiry model had an effect size value of .51 in developing students' SPS when compared with conventional teaching method. In a study conducted by Alemli (2019), average effect size was found as .48; while it was found as .88 in a study conducted by Akkaya (2019) and as 1.12 in a study conducted by Karakuş and Yalçın (2016). Considering that effect size was .74 in this meta-analysis which included 100 studies, it is possible to say that there are significant effect size differences between the results obtained. It is possible that the differences in these studies, the lowest of which had .48 effect size and the highest of which had 1.12 effect size may be caused by the sample sizes of studies, application periods, changes in educational levels and the fact that national/international studies or practitioners do not have sufficient experience about SPS.

Although the year range of this meta-analysis was large, it was found that the number of studies in which SPS was measured was not as common as academic achievement. Significant difficulties are considered as the fact that measuring SPS requires experience, takes time in terms of application, and requires providing equipment and environment for experiments in which hypotheses will be tested (Coştu, Ayaş, Çalık, Ünal, & Karataş, 2005). For these

reasons, it can be said that the scope of the study was narrow. Another limitation is the fact that the data in the accessed studies are missing; that is, the statistical results required for calculation effect size are not given or they are not given completely. This will cause a negative effect on generalizing the results of the study.

The studies included in the meta-analysis were grouped in sub-categories and comparisons were made. The first comparison is on the publication type of studies and a classification of scientific article, master's thesis and doctoral thesis was made. It was found that effect size values differed significantly in terms of type of study and this difference was in favour of master's theses and articles when compared with doctoral theses. When the literature was reviewed, it was found that in the meta-analysis by Karakuş and Yalçın (2016), articles on SPS were not included in the study; while only articles were included in the study by Miranti, Abdurrahman, and Ertikanto (2018) and therefore it was not possible to make comparisons with the results of these studies. It was found that the results of Akkaya (2019) and the results of the present study were different from each other. Unlike this study, Akkaya stated that the studies included in the meta-analysis did not differ significantly in terms of the publication type (article, master's, doctoral). In addition, Akkaya stated that the publication type with the lowest effect size was articles, while the publication type with the highest effect size was master's theses. The results of Akkaya's study and the present study showed significant differences and the reason for this difference is thought to be the different number of studies included in the meta-analyses. There were 6 articles conducted between 2006 and 2018 in Akkaya's study, while there were 32 articles in the present study between 1999 and 2020. It is thought that this quantitative difference was an important factor in the emergence of the difference between the results.

The second comparison of the study was about whether effect size differed by the years studies were conducted in. In the present meta-analyses, studies conducted between 1999 and 2020 were classified as 2009 and before, between 2010 and 2014 and 2015 and after. In this classification, the effect size of the studies conducted in 2015 and beyond was found to be higher than the studies in other categories. It was also found that effect size value increased as the year of studies increased, while this difference was not statistically significant. This result can be associated with student centred education entering teaching programs in schools affiliated with the Ministry of National Education in 2005 (Acat and Dönmez, 2009) because 2005 education program that was put into effect in 2005 was effective in the emergence of many new practices in education in Turkey. This may have caused new studies to plan designs with high internal and external validity by considering the recommendations of previous studies. Thus, experimental designs were planned more carefully, and effect level of learning products may have increased. When the literature was reviewed, it was found that while some of the results of the present study were in parallel with some of the results of Akkaya (2019), the result that effect size increased as study year increased was different. While the highest effect size was found in most recent studies in Akkaya's study as in the present study, the lowest effect size was found in earliest studies in the present study and in moderate category studies in Akkaya's study. This may have resulted from the fact that groups were dated differently in both studies.

Another variable in which the effect size values were compared was the level of education the study was conducted on. According to the results, although the level of education with the highest effect size was university, the level of education with the lowest effect size was high school. This result is in parallel with the results of the study conducted by Miranti, Abdurrahman, and Ertikanto (2018). The reason for this difference can be said to result from

the developmental differences in individuals. According to the cognitive development theory of Piaget, schemas of individuals are formed by the knowledge gained from the environment throughout the development process. If the new information acquired does not match the existing schema, an imbalance occurs, and mental development is provided as a result of the elimination and regulation of the imbalance. Individuals' experience is extremely important in regulation skills. Since the fact that university students will have more knowledge than the other levels of education and this will increase their experience, it can be said that the students at this level have higher cognitive development. It can be said that student centred teaching practices are understood and internalized more easily by university students.

When the application periods of experimental studies were compared in terms of categories, it was found that the effect size between them was not significant. It was found that 11 studies, the application periods of which were not found since they were not explained in the studies, had higher effect size than the studies in other categories. In studies with a specific application period, no conclusion was reached on whether effect size increased or decreased according to application period. The fact that there was no tendency in effect size value in terms of application period was also found in Akkaya (2019)'s study. The fact that the effect size of 32 studies with 5-8 weeks of applications (.59) in the present study was significantly higher than the effect size value of 18 studies (.98) analyzed within the same period of time by Akkaya is an important difference between the two studies. The fact that there were no studies in literature according to the application periods of studies limits discussing the reasons of this situation.

When comparisons were made according to the number of students in experimental studies, no significant difference was found between effect size values. According to the result of this study, the decrease in the number of students in the experimental study does not cause a significant difference; however, it contributes to the increase in the effect size for developing SPS of the students. In other words, the fewer the number of students in an experimental study is, the more possible it will be to increase the effect size of studies conducted. When compared with the results of Akkaya's (2019) study, it was found that the results obtained did not match. The most important factor in the emergence of this situation can be shown with the fact that the number of studies on a group of 0-29 was 1. Since only the results of 1 study were given in this category, it was not possible to compare the effect size values obtained with the results of this study. Since there were no other studies to compare in literature, it was considered that the data obtained as a result of this study were valid. When factors that threaten internal validity such as the decrease in the number of students in the study, loss of subjects, and choosing subjects are checked, this facilitates the design and conduct of experimental studies. Although large samples are generally better than small samples, very large sample may lead to wrong conclusions, especially in experimental studies (Mills and Gay, 2019).

In another analysis in this study, effect sizes of national and international studies were compared. 31 of the studies were in international category and the effect size of the remaining 69 national studies was partly higher when compared with international studies. Since there were no meta-analyses in literature to compare this finding, it was not possible to discuss the findings. However, close effect size values of national and international studies were evaluated as the results within the scope of this variable being more consistent with each other when compared with other studies.

Recommendations

This study discussed the effects of applications carried out by different subject areas and science methods on students' SPS levels; other variables such as academic achievement, attitude and motivation were not included. It can be recommended to determine the effects of SPS on different dependent variables by using meta-analysis. Besides, while studies conducted in science were included in the present study, studies conducted in the fields of mathematics and engineering were not included. Considering that STEM (Science, Technology, Engineering, and Mathematics) became popular recently, researchers planning to conduct meta-analysis studies in the future can bring together studies in the fields of technology, mathematics, and engineering and conduct analyses.

When studies conducted in science education were examined, it was found that SPS was affected more in some and less in others. Many factors such as the practitioner, duration of application, and sample may have been effective in the emergence of different results. The experience of practitioners, especially about measuring SPS, has an important place in conducting the process. Individuals should be made active while conducting SPS's experiences, and they should not try to perform the steps precisely as they are given in the teacher's instructions. Different researchers have found that meaningful learning does not occur in studies where the instructions are made as they are given (Abell and Volkmann, 2003; Hofstein et al., 2005; Renner, 1986; Roth, 1994). In this context, to apply the experimental design effectively, competencies of teachers of science and academics should be found, and their deficiencies should be dealt with through in-service training.

In this study, the overall effect size studies on the effectiveness of the student-centred learning approach in science on SPS was calculated as .78. According to Cohen's effect size classification, the values between .50 and .80 are accepted as a moderate level of effect; therefore, the overall effect size of .78 is accepted as a moderate level of effect. This effect size value calculated is criterion-related with SPS for researchers. In future studies on SPS, researchers can compare the effect size values of their studies with the results of this study. Besides, it was found that student-centered approaches in which SPS is measured positively affect science lessons compared with traditional methods. Therefore, it can be recommended for science teachers who expose their students to active learning environments to determine or measure SPS's outcomes.

Considering the sample sizes in the studies included in the meta-analysis, it was found that studies were mainly conducted at secondary education and university level, and there were few studies conducted on primary education and high school student groups. In this context, it can be recommended for researchers who will conduct new studies to carry out studies on student groups at primary education and high school level. In addition, it can be said that instead of conducting the experimental design in which SPS is measured on huge groups, running this design on participants between 30 and 54 will have positive effects on sample size.

Some of the studies planned to be included in this study were not accessed. Although some of them were accessed, they were excluded due to the missing data in them. For the generalizability of quantitative research data, researchers need to share their studies conducted with experimental design. Due to the nature of scientific research, it is an expected situation to present the data in a complete and unbiased way. In this context, it can be said that researchers' being careful about the basic statistics they need to present in scientific studies, juries, and editors and referees to control theses and articles more carefully will contribute to

decreasing errors. In Turkey, the concept of SPS began to be used with the Science and Technology lesson which went into effect in 2005. Most of the studies on SPS, which is considered a relatively new concept, are master's studies. That may cause them to have a higher margin of error when compared with doctorate studies. An increase in the number of doctorate studies can also decrease the level of error that can be seen in results. In line with this suggestion, effect sizes can be compared again in the future by taking into account the results of doctorate studies which increase in the following years.

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