Journal of Computer Education
Knowing is not enough, you must be able to do it.
Vol. 3(1), pp. 64-87, June 2024
https://www.journalofcomputereducation.info/

Effects of Coding and Robotics Activities on Computational Thinking and Problem-Solving Skills: A Meta Analysis Study

Jale Ulucan
Istanbul, Türkiye, ORCID: 0000-0002-6499-0328

M. Betul Yilmaz*
Computer Education and Instructional Technologies Department, Yildiz Technical University, Istanbul, Türkiye, ORCID: 0000-0003-4704-189X

Article history
Received:
21.04.2024

Received in revised form:
26.05.2024

Accepted:
28.05.2024

Key words:
Computational thinking, problem solving, meta-analysis, coding activities, robotics activities

The importance of coding and robotics education in the field of computer sciences has recently been a widely discussed and studied topic in research dealing with educational issues. It is acknowledged that the development of these skills plays a significant role in children's future careers. Therefore, the present study uses the meta-analysis method to examine the studies dealing with whether coding and robotics activities targeting pre-school, primary school, secondary school, and high school students have the potential to improve their computational thinking and problem-solving skills. To achieve this purpose, the study focuses on how coding and robotics activities implemented in experimental studies conducted with K–12 students between 2011 and 2021 affect the computational thinking and problem-solving skills of students. The meta-analysis includes data from 55 studies, consisting of 64 independent effect sizes. The participant pool for this analysis consists of 5158 individuals from different nations, with 3074 in experimental groups and 2084 in control groups. The study utilized the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols checklist. We used the courses that implemented coding and robotics activities, as well as the age ranges of the participants, as moderator variables. The moderator analysis revealed that the effect of coding and robotics activities on computational thinking and problem-solving skills differs according to age group. In conclusion, the present study found that coding and robotics activities contributed to the development of K–12 level students' computational thinking and problem-solving skills.

Introduction

Many countries in the world have started to offer coding-robotics courses in schools since they have expected that this education will considerably contribute to students' success in computational thinking and problem-solving skills. When we consider the current trend in the proliferation of coding/robotics education worldwide, we can see that 16 European countries, the USA, and some developed Far East countries have already integrated coding courses into their curricula as of 2013 (Balanskat & Engelhardt, 2015). ISTE (International

*Correspondency: beyilmaz@yildiz.edu.tr , mbetul.yilmaz@gmail.com

Society for Technology in Education) (2019) categorizes computational thinking as a type of analytical thinking and defines it as “combining human intelligence and the computing abilities of computers”. The primary purpose of coding-robotics education in schools is to encourage students to use computational thinking skills in other courses and in their daily lives, rather than make them computer science experts. Therefore, early coding education aims to foster the development of computational thinking and problem-solving skills in students.

There is a direct and close relationship between coding-robotics education and problem-solving skills. According to Aho (2012), a significant component of computational thinking skills is the ability to formulate a problem and develop appropriate problem-solution models to find effective solutions. Wing (2006), on the other hand, defines this skill as thinking processes that allow individuals to find the necessary solutions to process available information as effectively as possible. Thanks to coding-robotics activities, students can quickly and clearly identify problems and develop specific skills to evaluate a process and its consequences (Resnick & Silverman, 2005). Indeed, coding-robotics activities allow students to question a problem in their daily lives, evaluate the current situation by considering the past situation, and ultimately find a cause-and-effect relationship. Kızılkaya and Aşkar (2009), in their study, suggested that problem-solving skills can be categorized as "questioning", "evaluation”, and “reasoning”.

The literature lists some studies showing that coding-robotics activities contributed to more effective computational thinking and problem-solving skills. These studies reported positive findings regarding the fact that coding-robotics activities in classrooms helped students improve their computational thinking and problem-solving skills. To illustrate, Brown et al. (2008) conducted a study with secondary school students and examined the effect of classroom instruction based on Scratch, a block-based coding tool, on their computational thinking skills. The study involved asking one group of 5th and 6th year students to solve some mathematics problems, and another group to use Scratch to solve these problems. The results showed that the instruction accompanied by Scratch positively affected students’ computational thinking skills. Uşengül (2019), in his study carried out by using the LEGO Wedo 2.0 robotics instruction set, examined the effect of robotics-supported science lessons on students’ computational thinking skills. The findings revealed that the computational thinking skills of students receiving a robotics-supported science education significantly differed when compared to those receiving a science education not supported by robotics. In other words, robotics-supported science education positively affected these students’ computational thinking skills. Numanoğlu and Keser (2017) found that the mBot robotics set, an educational robotics set, allowed students to concretize abstract concepts in programming education and observe the immediate effect of the developed program. Furthermore, students reported that they were able to improve their computational skills more easily and effectively and form strong associations between programming lessons and real-life events.

In contrast, the findings of some studies reported that such instructional activities did not have any effects on computational thinking or problem-solving skills. For instance, after 11 weeks of robotic programming instruction, sixth- and seventh-grade pupils showed no significant increase in their computational thinking abilities, according to Noh and Lee (2020). Similarly, Ramazanoğlu (2020) discovered no significant difference in students' computational thinking skills after a 10-week robotics training for vocational high school students.

The present study aims to determine the extent to which coding and robotics activities affect computational thinking and problem-solving skills by performing a meta-analysis of the studies focusing on this specific issue. To achieve this purpose, the study will try to seek answers to the following questions:

(1) To what extent do coding and robotics activities contribute to computational thinking and problem-solving skills?
(2) Is "age group" a determining factor in the effect of coding-robotics activities on computational thinking and problem-solving skills?
(3) Is "course type" a determining factor in the effect of coding-robotics activities on computational thinking and problem-solving skills?

The findings of the first research question will contribute to our understanding of the impact of coding and robotics activities, which have seen an increase in popularity in recent years, on the computational thinking and problem-solving abilities of students at the K12 level. We think the results obtained for the second and third research questions will provide concrete insights into which age groups and courses will benefit the most from these activities. We hope that these findings will help teachers who integrate coding and robotics activities into their lessons.

Methodology

Research Design

The study employed the meta-analysis method to determine the effect of coding and robotics activities on students' computational thinking and problem-solving skills. This method allows researchers to examine the data from the previously conducted studies; an overall picture is obtained from these findings, and the effect of coding and robotics activities on students' computational thinking and problem-solving skills is clearly depicted.

The study utilized the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) checklist, developed by Moher *et al.* (2009), to standardize all systematic compilation studies, including meta-analysis. The present study did not include the first 5 items of this checklist, as the previous section already presented the procedures for items 1, 2, 3, 4, and predetermined aims. We explain the steps taken for the sixth item in detail below. We skipped and did not report some PRISMA-P steps because they did not align with the present study's aim.

Data Collection Process

The Criteria for the Inclusion of the Available Studies into the Meta Analysis (PRISMA-P Item 6)

Prior to the study, we determined specific criteria for the inclusion or exclusion of the available studies in the present study. We included the studies in the study if they satisfied the following criteria: being conducted between 2011 and 2021; written in Turkish or English; having open access; implementing coding and robotics instruction only for the experimental group; providing arithmetic means and standard deviation values regarding students' computational thinking and problem-solving skills; presenting the data about sampling size; using pre-school, primary school, secondary school or high school students as participants; being dissertations written for postgraduate programs or articles published in the academic journals accessed in predetermined electronic databases; and presenting data regarding sampling size, arithmetic means, differences between means, standard deviation, t and p values for the independent variables so as to calculate effect size.

Information Sources and Review (PRISMA-P Item 7 and Item 8)

The present study examines studies dealing with the effects of coding and robotics activities on computational thinking and problem-solving skills in order to find answers to the research questions. Thus, the researchers decided to use journal articles and dissertations available in YÖK TEZ, DergiPark, ULAKBİM, Google Scholar, ProQuest, EBSCO, ERIC, Science Direct, and Web of Science electronic databases as the information sources for the study. YÖK TEZ is a database listing all master's and PhD degree dissertations completed in Turkey. ULAKBIM and DergiPark are journal databases that index journals published in Türkiye and are regularly evaluated by TÜBİTAK officially in terms of quality. The first access was on February 28th, 2021, and the final update for the data was on November 1st, 2021. A total of 126,207 publications were accessed.

Study selection (PRISMA-P Item 9)

The study examined experimental studies conducted in the previous ten years, focusing on the contribution of coding and robotics activities implemented in pre-school, primary school, secondary school, and high school to students' computational thinking and problem-solving skills. The studies listed in the database searches involved the following phrases in their titles and keyword sections in Turkish and in English ("Computational Thinking and Coding Education", "Computational Thinking and Code Education", "Computational Thinking and Robotic Education", "Problem Solving and Code Education", "Problem Solving and Robotic Education"). We used full texts for further details.

Data Collection Process (PRISMA-P Item 10)

The meta-analysis excluded the studies that did not meet the predetermined criteria (conducted in the last ten years, involving the education levels of pre-school, primary school, secondary school, and high school, and measuring the effect of coding and robotics activities on computational thinking and/or problem-solving skills), as well as duplication studies. We also excluded studies with restricted access. After the exclusion procedure, there were 9928 studies remaining.

Study selection (PRISMA-P Item 17)

Two observers (the researcher's supervisor and an instructor with experience in meta-analysis) debated whether each study should be included or excluded. They reached a consensus on the results without any conflicts and subsequently verified the obtained findings. Figure 1 below presents the flow diagram for this process.

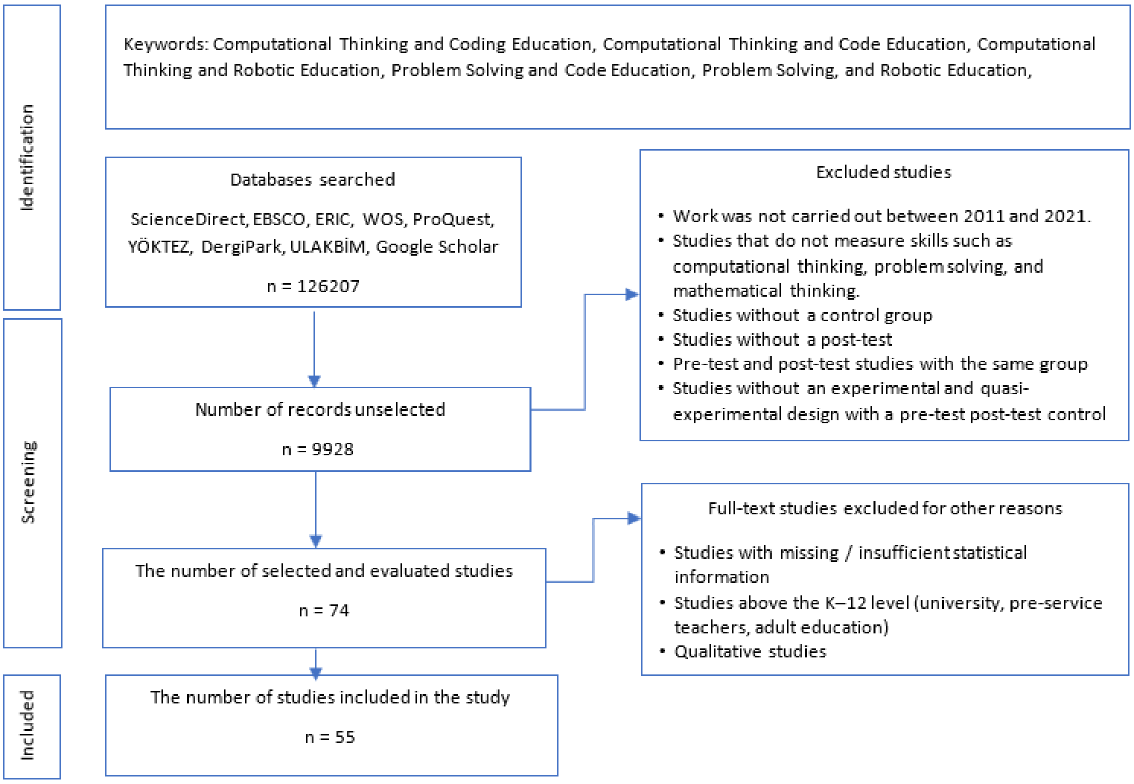

Figure 1. Flow Diagram for Study Selection

We developed a 17-item coding form after determining which studies to include in the meta-analysis. The first and second items in the coding form define the study, while items 3-6 provide information about the suitability of the studies for the meta-analysis (model, design, data collection instrument, technological tools used); items 7-9 pertain to descriptive statistics (country, authors, grade); and items 1–17 calculate the meta-analysis's effect size (duration of the experiment, sample and control group sizes and averages, among other factors).

Study Characteristics (PRISMA-P Item 18)

Table 1 below presents the dependent, independent, and moderator variables derived from the studies this meta-analysis examined.

Table 1. Dependent, Independent and Moderator Variables.

Dependent Variable	Independent Variables	Moderator Variables
• The effect of coding and robotics activities on computational thinking and problem-solving skills	• Year range (2010-2021) • Sampling size • Type of publication • The country where the study was conducted • The type of school where the study was conducted • The program and materials used in the study • The duration of the study	• The ages of the participants with whom the study was conducted • The course/discipline in which coding and robotics activities were practiced

The meta-analysis included 33 studies (51.6%) with secondary school students, 14 (21.9%) with primary school students, 12 (18.8%) with pre-school students, and 5 (7.8%) with high school students. Figure 2 displays the distribution of the studies included in the study according to years.

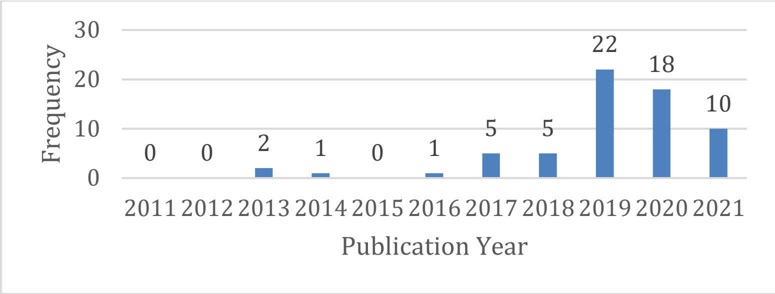

Figure 2. Distribution of the Examined Studies According to Years

Figure 2 shows that in 2011, 2012, and 2015, no studies examined the impact of coding and robotics activities on computational thinking and problem-solving skills. The number of studies conducted noticeably increased as of 2017, and the highest number was 22 (34%) in 2019. The number of experimental studies on this issue slightly decreased in 2020 and 2021, which might be because of worldwide COVID-19 pandemics.

The distribution of the studies examined within the framework of the meta-analysis reveals that 40 studies (62.5%) were articles, 15 (23.4%) were master's degree dissertations, and 9 (14.1%) were PhD dissertations. Table 2 below displays the distribution of the examined studies according to countries.

Table 2. Distribution of the Examined Studies According to Countries.

Country	Frequency	Percentage
Türkiye	35	54.7
Spain	14	21.9
USA	5	7.8
Philippines	2	3.1
Italy	2	3.1
Korea	2	3.1
Taiwan	2	3.1
Australia	1	1.6
China	1	1.6

The findings presented in Table 2 reveal that the majority of the studies that were analysed were conducted in Türkiye with 35 (54.7%) studies, followed by Spain (14 studies, 21.9%), and the USA (5 studies, 7.8%). Table 3 below presents the data regarding the sampling size in the studies examining the impact of coding and robotics activities on computational thinking and problem-solving skills.

Table 3. Distribution of the Studies According to Sampling Size.

Sampling Size	Frequency	Percentage
0-50	27	42.18
50-100	18	28.12
100-150	16	25.0
150 and above	3	4.68

Table 3 shows that the sampling size range with the highest percentage (42%) is the 0–50 range. It is noteworthy that the study percentage decreases as the sample size increases. Table 4 lists the robotics sets and special software used in coding and robotics activities.

Table 4. The Programs and Materials used in Coding and Robotics Activities.

Programs and Materials	Frequency	Percentage
Mixed (Coding-Robotics-Unplugged)	18	28.1
Lego WeDo 2.0	6	9.4
Coding (not specified)	6	9.4
Scratch	5	7.8
Lego Mindstorms NXT	4	6.3
Unplugged Activities	3	4.7
Arduino	3	4.7
STEM-based Instruction	2	3.1
Lego Mindstorms EV3	2	3.1
TurtleBot	2	3.1
Beebot	2	3.1
Vphysics	2	3.1
mBot - mBlock	2	3.1
Algorithms	1	1.6
Code.org	1	1.6
iDea	1	1.6
Kodu Game Lab	1	1.6
Flowchart	1	1.6
Robot City board game	1	1.6
KIBO Robot	1	1.6

Table 4 shows that the mixed method (18 studies; f = 18) is the most used method in the meta-analysis. This method involved teaching the students using both block- or text-based software, unplugged activities, and robotics sets. Also, the study utilized various programming methods, techniques, tools, and instruments such as LEGO WeDo 2.0 (f = 6), Scratch (f = 5), and LEGO Mindstorms NXT (f = 5). Table 5 presents the durations of the activities used in the studies included in the meta-analysis.

Table 5. Activity Duration in the Examined Studies.

Duration of the Activity during experimentation	Frequency	Percentage
2-4 weeks	11	17.19
5-8 weeks	23	35.94
9-12 weeks	18	28.13
13-18 weeks	5	7.81
One or more semester	3	4.69
Not specified	4	6.25

According to the results presented in Table 5, the experimental studies included activities that lasted between 5 and 8 weeks at most. Conversely, activities that span a semester or longer are the least frequent.

The study's dependent and independent variables have received explanations thus far. Additionally, moderator variables are explained. The meta-analysis's studies included pre-school, primary school, secondary school, and high school students; in other words, the 3–18 age group participated in the studies included in the analysis. Table 6 below displays the age groups' frequencies.

Table 6. Distribution of Age Groups in the Examined Studies.

Age Groups	Frequency	Percentage
3-5 years old	10	15,6
5-12 years old	38	59,4
12-18 years old	11	17,2
3-12 years old	1	1,6
5-18 years old	4	6,3

Table 6 reveals that the meta-analysis included 38 studies with participants in the 5–12 age group, followed by 11 studies with participants in the 12–18 age group and 10 studies with participants in the 3-5 age group. We added two more moderators (3-12 and 5-18 age groups) to the meta-analysis due to the wide age range in some studies and the unclear number of participants from each age group.

The courses or disciplines that practice coding and robotics activities are another moderator variable in the present study. The study also examined the effectiveness of coding and robotics activities according to the course type. Table 7 below presents the distribution of the examined studies included in the meta-analysis by course type.

Table 7. Distribution of the Analysed Studies According to the Courses.

Course	Frequency	Percentage
Computer science	21	32,8
Pre-school activities	12	18,8
Science	10	15,6
Extra curricula	10	15,6
Mathematics	6	9,4
Art education	4	6,3
Spanish	1	1,6

21 (32.8%) studies included in the meta-analysis examined the effect of coding and robotics activities on computational thinking and problem-solving skills for computer science lessons, followed by science lessons and preschool activities.

Data Analysis

This section outlines the steps taken to analyse the data for this meta-analysis study.

Risk of Bias in Individual Studies (PRISMA-P ITEM 12)

It is critical to report the presence or absence of a bias in the studies included in the meta-analyses. There are numerous reasons for publication bias. Some possible reasons include inadequate literature reviews, the inclusion of studies with small sample sizes, language barriers, and studies that researchers fail to access. Because of the language barrier, the meta-analysis only included publications written in Turkish or English.

This meta-analysis study employs a method based on database selection to minimize the risk of publication bias. We selected the databases for this study based on their national and international recognition and prestige. We minimized publication bias by assuming that these databases apply stricter criteria to accept articles and dissertations than other databases.

The meta-analysis in this study included a total of 55 studies with 64 effect sizes. We used the effect sizes funnel chart to assess the presence of publication bias, the classic fail-safe number, and the Duval and Tweedie Trim-Fill method. We also examined the forest plot, which displays effect sizes. Figure 3 presents the funnel chart for the studies.

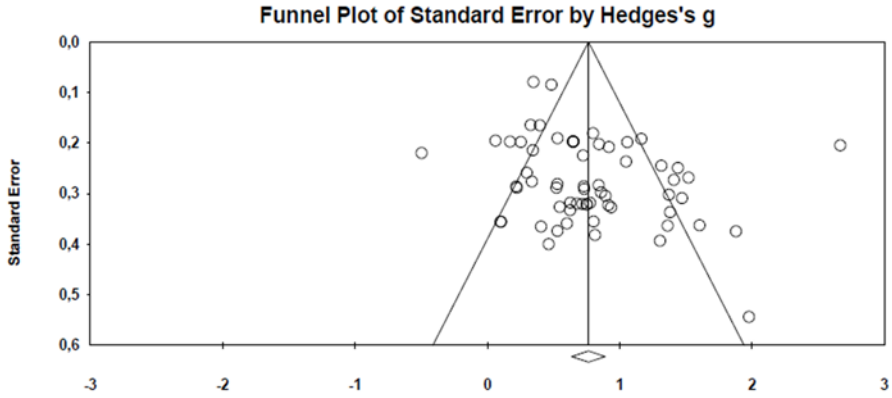

Figure 3. Funnel plots with pseudo 95% confidence limits of 64 effect sizes

Figure 3's funnel graphic represents each individual study as a circle. Studies to the left of the 0 value suggest that the meta-analysis included both positive and negative effect sizes. In addition, the funnel chart shows that the studies accumulate on the upper section of the chart, which indicates that the studies examined in the meta-analyses had a large sampling size. We can conclude from Figure 3 that there is no publication bias, but we also performed the classic fail-safe N test to obtain more accurate results.

According to Dinçer (2014), the classic fail-safe N test indicates the number of studies required to interpret a study's result as insignificant, meaning the p value (0.000) should be higher than the alpha value (0.05). Table 8 displays the findings regarding this analysis.

Table 8. Classic Fail-safe N Test Findings.

z-value for the examined studies	23.86719
p-value for the examined studies	0
Alpha	0.05
Tail	2
Z-value for alpha	1.95996
Number of examined studies	64
Number of studies required to refute significant meta-analytic means (p>0.05)	9427.00

The findings in Table 8 reveal that the number of studies showing that coding and robotics activities have a zero effect on computational thinking and problem-solving skills should be 9427 to invalidate the meta-analysis result. This value is much higher than the double of 64 (the total number of studies). There is a very low probability that there are 9427 studies in the literature reporting a similar result. Therefore, the N fail-safe number shows the lack of publication bias in study findings and supports the hypothesis that these findings are valid.

The above analysis confirms the absence of publication bias in the meta-analysis. This is critical in terms of determining whether the effect size is the result of bias and whether the study is reliable and valid. In summary, we can conclude that meta-analysis findings are valid and reliable due to the absence of publication bias in the studies that provide data on the research questions.

Meta-Analysis Calculations

All the calculations and comparisons in the present study were made using Comprehensive Meta Analysis (CMA) statistical software, which was also utilized to determine overall effect size and publication bias and to create certain graphics such as forest plots and funnel plots. The meta-analysis method calculates effect sizes using quantitative data. Effect size can be defined as the measurement of the difference between the experimental group and the control group (Cohen, 1988). The effect size in the present study was calculated using Hegdes's g value. The study also adopted both Cohen's d and Thalheimer and Cook's (2002) effect size classification.

Effect sizes are often calculated by employing a fixed effects model or a random effects model. The random effects model is more appropriate in meta-analysis studies when they do not have the same design and methodology for sampling. In other words, the studies using the random effects model should be heterogeneous. We measure heterogeneity while determining which model to adopt using Cochran statistics and the I^2 value. When choosing a model from an existing list, the Cochran Q value proves to be useful and effective. We use Q statistics to test heterogeneity, and I^2 is used to determine the degree of heterogeneity. When the Q value surpasses the Chi-Square value, it signifies the existence of heterogeneity among studies, necessitating the application of the random effects method. Otherwise, a fixed effects model should be used. The present study takes into consideration the I^2 statistics reference points proposed by Higgins (2003).

The study also conducted moderator analyses. This analysis allows researchers to test the direction of differences between sub-groups (Littel *et al*., 2008). The present study uses only Q values because the primary goal is to determine whether the differences between moderators are statistically significant or not. We examine and evaluate Q statistics to determine the presence or absence of statistical significance in the differences between moderator variables. We set the confidence interval at 95% for all calculations.

Results

From the total of 55 selected articles, there are 64 effect sizes and 5158 participants, of which 2084 belong to control groups and 3074 to intervention groups. The average number of participants per article is 93.78 individuals. The range of participants is 829, from a minimum of 19 to a maximum of 848 participants. This section introduces the findings regarding the research questions in the meta-analysis.

Results of Individual Studies (PRISMA-P Item 20)

It is necessary to calculate the effect values of individual studies first so that we can obtain meta-analysis findings regarding the effect of coding and robotics activities on the computational thinking and problem-solving skills of students. Accordingly, arithmetic means ($\bar{x}$), experimental-control group sampling sizes (N), standard deviation values (S), and p values for each individual study were analysed using CMA software, and effect sizes were calculated separately for each study and presented in Table 9.

Table 9. Individual Effect Sizes (ES) of the Examined Studies.

Number of the Study	Hedges's g ES	Sd	s^2	Lower Bound	Upper Bound	z-Value	p-Value
Study 1	0.173	0.197	0.039	-0.214	0.559	0.876	0.381
Study 2	0.407	0.365	0.133	-0.309	1.122	1.114	0.265
Study 3	0.649	0.197	0.039	0.263	1.036	3.296	0.001
Study 4	1.315	0.245	0.06	0.836	1.795	5.375	0.000
Study 5	1.305	0.393	0.155	0.535	2.076	3.319	0.001
Study 6	1.521	0.268	0.072	0.995	2.046	5.67	0.000
Study 7	0.732	0.291	0.085	0.162	1.302	2.518	0.012
Study 8	0.349	0.079	0.006	0.194	0.504	4.419	0.000
Study 9	0.814	0.382	0.146	0.066	1.562	2.133	0.033
Study 10	0.1	0.356	0.126	-0.597	0.797	0.282	0.778
Study 11	0.224	0.288	0.083	-0.341	0.789	0.777	0.437
Study 12	0.627	0.318	0.101	0.005	1.25	1.974	0.048
Study 13	0.548	0.326	0.106	-0.091	1.188	1.681	0.093
Study 14	1.879	0.374	0.14	1.145	2.613	5.019	0.000
Study 15	0.649	0.197	0.039	0.263	1.036	3.296	0.001
Study 16	0.73	0.286	0.082	0.17	1.289	2.556	0.011
Study 17	0.86	0.297	0.088	0.277	1.443	2.893	0.004
Study 18	1.471	0.309	0.095	0.866	2.077	4.763	0.000
Study 19	0.254	0.198	0.039	-0.134	0.642	1.285	0.199
Study 20	0.753	0.321	0.103	0.123	1.382	2.344	0.019
Study 21	1.363	0.363	0.132	0.651	2.075	3.752	0.000
Study 22	0.53	0.281	0.079	-0.021	1.081	1.885	0.059
Study 23	0.914	0.323	0.104	0.282	1.547	2.835	0.005
Study 24	0.777	0.318	0.101	0.153	1.401	2.442	0.015
Study 25	1.978	0.544	0.296	0.912	3.044	3.638	0.000
Study 26	0.936	0.327	0.107	0.294	1.577	2.86	0.004
Study 27	0.752	0.321	0.103	0.122	1.381	2.341	0.019
Study 28	1.382	0.337	0.113	0.722	2.041	4.104	0.000
Study 29	0.626	0.333	0.111	-0.026	1.278	1.882	0.060
Study 30	0.602	0.359	0.129	-0.101	1.306	1.678	0.093
Study 31	0.219	0.286	0.082	-0.341	0.779	0.765	0.444
Study 32	0.531	0.374	0.14	-0.202	1.263	1.42	0.156
Study 33	0.523	0.288	0.083	-0.042	1.088	1.815	0.07
Study 34	1.41	0.273	0.074	0.875	1.945	5.17	0.000
Study 35	0.803	0.355	0.126	0.107	1.499	2.262	0.024
Study 36	0.299	0.259	0.067	-0.208	0.806	1.155	0.248
Study 37	2.667	0.204	0.042	2.266	3.068	13.044	0.000
Study 38	0.345	0.214	0.046	-0.075	0.765	1.61	0.107
Study 39	0.724	0.225	0.05	0.284	1.165	3.227	0.001
Study 40	0.338	0.276	0.076	-0.203	0.879	1.224	0.221
Study 41	1.058	0.198	0.039	0.67	1.447	5.34	0.000
Study 42	-0.496	0.22	0.048	-0.926	-0.066	-2.259	0.024
Study 43	0.845	0.202	0.041	0.449	1.241	4.18	0.000

Study 44	0.063	0.195	0.038	-0.32	0.445	0.322	0.748
Study 45	0.485	0.085	0.007	0.319	0.65	5.732	0.000
Study 46	0.464	0.4	0.16	-0.319	1.248	1.161	0.246
Study 47	0.678	0.32	0.102	0.051	1.304	2.119	0.034
Study 48	0.531	0.19	0.036	0.158	0.904	2.788	0.005
Study 49	0.719	0.32	0.103	0.091	1.347	2.245	0.025
Study 50	0.894	0.304	0.093	0.297	1.49	2.935	0.003
Study 51	0.799	0.181	0.033	0.445	1.153	4.424	0.000
Study 52	1.164	0.192	0.037	0.789	1.54	6.074	0.000
Study 53	0.919	0.208	0.043	0.512	1.327	4.424	0.000
Study 54	1.372	0.302	0.091	0.78	1.964	4.543	0.000
Study 55	0.842	0.283	0.08	0.287	1.397	2.972	0.003
Study 56	0.398	0.165	0.027	0.075	0.721	2.416	0.016
Study 57	0.328	0.164	0.027	0.006	0.65	1.999	0.046
Study 58	0.649	0.197	0.039	0.263	1.036	3.296	0.001
Study 59	0.649	0.197	0.039	0.263	1.036	3.296	0.001
Study 60	0.649	0.197	0.039	0.263	1.036	3.296	0.001
Study 61	0.105	0.356	0.126	-0.592	0.802	0.295	0.768
Study 62	1.049	0.237	0.056	0.585	1.512	4.434	0.000
Study 63	1.441	0.249	0.062	0.953	1.929	5.785	0.000
Study 64	1.604	0.363	0.131	0.893	2.315	4.424	0.000

The data presented in Table 9 shows that the highest effect size was in Study 37 (perfect effect) (ES = 2.667), while Study 42 (ES = -0.496) was the only study with a negative effect level. Table 10 displays the distribution of the calculated effect values for the studies according to the classification based on Thalheimer and Cook's (2002) effect ratios.

Table 10. Frequency and Percentage Values according to the Classification of Effect Sizes for the Examined Studies.

Level of ES	Range of ES	Frequency	Percentage
Insignificant	-0.15 ≤ES <0.15	4	6.3
Small	0.15 ≤ES <0.40	10	15.6
Medium	0.40 ≤ES <0.75	21	32.8
Large	0.75 ≤ES <1.10	15	23.4
Very Large	1.10 ≤ES <1.45	8	12.5
Perfect	1.45 ≤ES	6	9.4

Findings in Table 10 show that four of the 64 studies examined within the scope of the research have insignificant impact values, 10 have small impact values, 21 have medium impact values, 15 have large impact values, 8 have very large impact values, and 6 have excellent impact values.

Synthesis of Results (PRISMA-P Item 21)

It is necessary to synthesize the findings through meta-analysis to understand the effect of coding and robotics activities on computational thinking and problem-solving skills. Table 11 presents the findings of these analyses.

Table 11. Overall Effect Size for the Examined Studies.

Model	Effect Size and %95 Confidence Interval								Heterogeneity			
	Number of Studies	ES	SE	s^2	Lower Bound	Upper Bound	z	p	Q	df	p	I^2
Random Effects	64	0.764	0.064	0.004	0.639	0.89	11.92	0.000	288.98	63	0.000	78.199

To achieve this purpose, first the model to be used should be selected using I^2 statistics. The analysis's results revealed a Q (df = 63) statistic value of 288,98 (p<0.000). We can conclude that the data were heterogeneous because the Q value exceeded 63 degrees of confidence, as indicated in the chi-square table, at a 95% confidence level. Thus, the calculated I^2 value for the studies included in the analysis was 78, which implies a high level of heterogeneity, according to Higgins (2003). Therefore, the selected random effects model was appropriate for the analysis.

At this stage, we performed the final check for publication bias using the Duval and Tweedie Trim-Fill Method and presented the findings in Table 12 *(PRISMA-P Item 22)*.

Table 12. the Duval and Tweedie Trim-Fill Analysis for Random Effects Method.

Random Effects Model	Excluded Study	Effect Size	Lower Bound
Observed Values		0,76427	0,63860
Corrected Values	0	0,76427	0,63860

As shown in Table 12, the "corrected value" was calculated as zero, which might suggest that it is not necessary to take action to correct publication bias. In other words, a meta-analysis study lacks publication bias. In addition, a forest plot (see Figure 3), which displays the distribution of individual effect size values according to a random effects model, was examined, and 63 studies out of 64 were found to have a positive effect size.

Table 11's analysis, using the appropriate model and without publication bias, found that the overall effect size of coding and robotics activities at K12 level on students' computational thinking and problem-solving skills was 0.764 for the 64 included studies. This value is in the medium category ($0.21 \leq d < 0.79$) in Cohen's small-medium-large effect size classification. Here it should be noted that the effect size value of 0.764 is close to the upper limit of the medium. Similarly, in the classification of Thalheimer and Cook (2002), the $0.75 \leq d < 1.10$ range is defined as a large level.

In conclusion, the answer to the first research question is: "Coding and robotics activities have a positive and considerable effect on students' computational and problem-solving skills".

Additional Analysis (PRISMA-P Item 23)

This section presents findings regarding the research questions addressing the effects of moderator variables.

The Moderator Effects of Age Groups and Course / Discipline on the Effect of Coding and Robotics Activities on Computation Thinking and Problem-Solving Skills

The study's second and third research questions are whether age group and course type influence the impact of coding-robotics activities on students' computational thinking and problem-solving skills. Table 12 displays the moderator analyses, including average weighted Hedges's g for different age groups and course/disciplines. It also presents the Q-test for heterogeneity and a 95% confidence interval for the analyses.

Table 12. Moderator Analysis on Age Group and Course / Discipline.

Moderator variables	Heterogeneity between groups (Q_B)	k	p	Overall ES (Hedges's g)	95% CI		Heterogeneity within groups (Q_w)
					Lower	Upper	
Age Groups							
3-5 years old		10	0.432	0.888	0.709	1.066	9.057
5-12 years old		38	0.000	0.738	0.594	0.882	124.842*
12-18 years old		11	0.000	0.588	0.338	0.838	32.258*
3-12 years old		1	1.000	0.485	0.319	0.650	0.000
5-18 years old		4	0.000	1.195	0.007	2.383	59.310*
Total	12.340*	64	0.015				
Course / Discipline							
Computer Science		21	0.000	0.774	0.466	1.081	154.561*
Science		10	0.001	0.713	0.431	0.995	28.168*
Spanish		1	1.000	0.299	-0.208	0.806	0.000
Mathematics		5	0.001	0.766	0.349	1.182	19.696*
Preschool activities		12	0.258	0.964	0.806	1.121	13.559
Art Education		5	1.000	0.649	0.477	0.822	0.000
Extra-Curricular activities		10	0.000	0.697	0.373	1.022	50.866*
Total	9.834	64	0.132				

Q_B Heterogeneity between the studies, Q_W Heterogeneity within the studies, *CI* Confidence interval, *k* Number of studies, *ES* Effect size in terms of *Hedges's g*, $Q_T = 288.98$, $I^2 = 78.199$, *: significant *p*-value associated with Q_B & Q_W (*i.e. p*- value < 0.05)

According to Table 12, the Q_B value was significant (p-value < 0.05) for the “age groups”, depicting that a significant difference existed between the individual studies. This finding reveals that, for some age groups included in the meta-analysis, coding and robotics activities have a significant contribution to students' computational thinking and problem-solving skills ($p<0.05$). In other words, the effect of coding and robotics activities was significantly greater for 5–12 years, 12–18 years, and 5–18 years groups than for 3-5 years and 3–12 years groups. Indeed, the p-value is not significant for the 3-5 and 3–12 year groups.

The results showed that students between the ages of 5 and 12, who conducted the most research, had the closest value to the average effect size (f = 38). The meta-analysis's examination of the effect sizes from each included study reveals that studies with students in the 5–18 and 5–12 age groups have the highest significant effect sizes at 1.195 and 0.788, respectively. However, the p-value does not indicate statistical significance for the effect sizes of the 3-5 and 3-12 age groups ($p > .05$).

In contrast to the findings above, the p value of the Q_B statistic for "course / discipline" is higher than 0.05. This indicates that groups are not significantly different from each other, and the statistical differences between the course / discipline are not significant (p = .132). In other words, the effects of coding and robotics activities conducted on different courses / disciplines were not different and did not influence the effectiveness of those activities.

Table 12 shows that the computer science course, which conducted the most research, had the value closest to the average effect size (f = 21). Although the effect of coding and robotics activities was not significantly different among courses / disciplines, the implementation of these activities in computer science, science, mathematics, and extracurricular courses has statistically significant effect sizes (respectively 0.774, 0.713, 0.766, and 0.697). In contrast, our analysis revealed that the effect size of Spanish, art education, and preschool activities was not statistically significant ($p > .05$).

To summarize, the only moderator that was significantly associated with variability in students' computational thinking and problem-solving skills was age groups ($Q_B = 12.340$, $p < .05$). In contrast, course / discipline was irrelevant ($Q_B = 9.834$, $p = .132$).

Discussion

This study conducted a meta-analysis to assess the overall effectiveness of experimental and quasi-experimental studies conducted in Türkiye and abroad between 2011 and 2021 on the effects of coding and robotics activities on computational thinking and problem-solving skills. In the study, which was limited by certain criteria, a total of 64 studies in the relevant literature were included in the meta-analysis, and these studies were evaluated in terms of their limitations and superior aspects. Table 13 summarizes the main findings.

Table 13. Key Findings of the Study.

	Findings	**Interpreting of findings**
Heterogeneity test	p is significant	The random effects model used
Publication bias	• 9427 additional studies are unlikely to be found. • absence of asymmetry in the funnel plot • No work is to be added or removed.	There is no bias based on the results of the funnel plot, the classical error-preserving N test, and the Duwal & Tweedie Trim & Fill analyses.
Effect size	ES = 0.764	In the margin of medium category depending on Cohen's d small-medium-large effect size classification, and in the large category depending on Thalheimer and Cook.
Result	p is significant	Coding and robotics activities are highly effective in improving students' computational thinking and problem-solving skills.

The overall effect size of the analysed studies was found to be 0.764 and interpreted in the large category based on Thalheimer and Cook's (2002) effect ratios (see Table 10). According to Cohen’s d effect size, this value is also highly closer to the large category of small-medium-large categories.

We performed some controls to detect publication bias. The first of these is the funnel plot. The funnel plot's lack of excessive asymmetry, the clustering of studies around the overall effect size, the classical N error protection number, and the absence of publication bias in the Duval and Tweedie Trim & Fill analyses suggest the absence of publication bias in this meta-analysis study.

All this finding reveals that coding and robotics activities have a positive and considerable effect on the computational thinking and problem-solving skills of students. This finding is consistent with the findings of similar meta-analysis studies on K12 students' computational thinking skills (Fidai, Capraro, & Capraro, 2020; Li *et al.*, 2022; Merino-Armero, González-Calero, & Cozar-Gutierrez, 2022; Sun, Hu, & Zhou, 2021b). Hedges's g value indicates a medium effect size in these studies, measuring around 0.600. The present study revealed that the effect of coding and robotics activities on students' computational skills was even greater.

Age groups, but not course or discipline, influenced the mean weighted effect sizes of coding and robotics activities on the computational thinking and problem-solving skills of students, according to the moderator analysis. We have discussed the individual moderator analyses' specific results below.

Age groups as moderator variables. The meta-analysis findings show that the effect size of coding and robotics activities is very large (ES=1.195) for the 5–18 age group, large (ES=.788) for the 5–12 age group, and medium (ES=.588) for the 12–18 age group, as categorized by Thalheimer and Cook (2002). All these effect sizes were statistically significant. Merino-Armero, González-Calero, and Cozar-Gutierrez (2022) reported in their study that programming/coding activities at different K12 levels except prekindergarten had similar effect values on computational thinking.

On the other hand, effect sizes were not statistically significant for the groups of 3–5 years and 3–12 years. This finding is consistent with Merino-Armero et al. (2022). Unlike the kindergarten and above levels, the prekindergarten group (3–5 year group) did not have a statistically significant effect size (Merino-Armero et al., 2022). In another meta-analysis study, Fidai et al. (2020) found that Arduino and Scratch-supported interventions in elementary, middle, and college settings had an overall positive effect on students' STEM academic achievement and perceptions towards STEM. However, the grade level of the students did not influence their computational thinking skills, according to the results of the meta-analysis study. Students' grade level did not have a moderating effect on computational thinking development in studies using programming exercises, according to a similar study (Li *et al*., 2022). We emphasize that both meta-analyses did not include kindergarten groups. In another recent meta-analysis, a statistically significant large effect size was found on the computational thinking and problem-solving skills development of 3- to 8-year-old children, providing empirical support for engaging young children in computational thinking experiences (Wang, Chan, Li, & Leung, 2023). The study's results also reveal that the moderator variable of education level significantly influences the effect size.

These findings suggest that more studies are required to explore the impact of coding and robotics activities for young learners on their computational thinking and problem-solving skills. It is not possible to clearly conclude the influence of coding and robotics activities on young learners computational thinking and problem-solving skills. On the other hand, at the elementary and secondary levels, coding and robotics activities can be suggested to improve students' computational thinking skills, depending on the results of the present study.

Course / discipline as moderator variables. The present study found that the type of courses / disciplines did not influence the effectiveness of coding and robotics activities. Li et al. (2022) have also revealed similar findings. Their meta-analysis study showed that the differences in influence between the interdisciplinary courses and the single computer science course in the programming education teaching approach were not significant. Several other meta-analyses came to different conclusions. These studies found that the influence of integrating programming activities into different disciplines on students' computational thinking skills differed significantly in heterogeneity (Merino-Armero *et al.*, 2022; Sun, Hu, & Zhou, 2021b). In other words, depending on these analyses, the sort of course / discipline that includes coding and robotics activities moderates the development of computational thinking (CT) skills.

The moderator analysis of the present study showed that coding and robotics activities had both significant and non-significant effects on students' computational thinking and problem-solving skills, no matter what course or discipline they were in. The meta-analysis findings suggest that coding and robotics activities have a large effect on computer science and mathematics, with effect sizes of 0.774 and 0.766, respectively. Similarly, these activities have a medium effect on science and extracurricular activities, with effect sizes of 0.710 and 0.697, respectively, as classified by Thalheimer and Cook (2002). All these effect sizes were statistically significant.

Sun, Hu, and Zhou (2021b) demonstrate that integrating programming activities into several topics, such as computer science, mathematics, STEM, language, biology, and physics, has a significant impact on students' computational thinking skills, with effect sizes ranging from medium to large. Similarly, Merino-Armero et al. (2022) found that all subjects, including programming, robotics, STEAM, science, computer science, informatics, mathematics, social sciences, art, and dance, exhibit medium, large, and very large effect sizes. The only exception was robotics, which demonstrates a low effect size.

However, the current study indicates that Spanish and art education courses, along with preschool activities, did not yield significant effect sizes. In their study, Sun, Hu, and Zhou (2021b) found that while the effect size was medium in the language course, it was not statistically significant in the music course. Merino-Armero et al. (2022) found a very large effect size in social science and art, a medium effect size in dance courses, and no statistically significant effect size in English. All these findings demonstrate that implementing coding and robotics activities has a notable positive impact on the development of computational thinking skills within subjects such as computer science and mathematics. However, the computational thinking outcomes of such activities appear to be inconsistent when applied to disciplines such as language, fine arts, social studies, and preschool activities.

Implications for Practice and Recommendations for Future Research

The research's conclusions have led to several significant recommendations. Firstly, we encourage educators and curriculum developers to incorporate coding and robotics activities into their courses to enhance students' computational thinking and problem-solving skills. We recommend incorporating these activities from preschool through high school, as they have proven beneficial in fostering these skills.

Furthermore, according to moderator analyses of different courses and disciplines, coding and robotics education are particularly effective in mathematics, computer science, and science courses. These subjects inherently promote skills such as problem-solving, analytical thinking, and evaluation. Thus, the inclusion of coding and robotics activities in these courses is highly effective in cultivating computational thinking and problem-solving skills. However, there is a need for additional research, particularly focusing on preschool groups, to better understand the impact and effectiveness of these activities at early educational stages.

Lastly, it is imperative to explore the application of coding and robotics activities in other disciplines, including language arts, fine arts, social studies, and preschool activities, to evaluate their potential benefits and implementation strategies in a broader educational context.

Acknowledgments

- The authors would like to thank Dr. Ebru Ulucan from Istanbul Ticaret University for her valuable contribution to the selection process of the studies.
- This article is based on the first author's master's thesis, written under the supervision of the second author.

References:

*Studies included in the meta-analysis are marked with *.*

Aho, A. (2012). Computation and computational thinking. *The Computer Journal*, *55*(7), 832-835. https://doi.org/10.1093/comjnl/bxs074

* Akcaoglu, M. (2013). *Cognitive and motivational impacts of learning game design on middle school children*. (Doctoral thesis, Michigan State University). URL: https://www.proquest.com/docview/1427344597?pq-origsite=gscholar&fromopenview=true&sourcetype=Dissertations%20&%20Theses

* Akyol Altun, C. (2018). *The effect of algorithm and coding education integration into preschool curriculum on students' problem solving skills.* (Master's thesis, Ankara University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=fS4sqEZr79C_n60Rk6MjFYnMwYK9I2U7N1rgF-YCxYwhvdVj3yRNFjiLvXrhSDlv

* Alp, Y. (2019). *The effect of block-based programming instruction on middle school students' problem solving skills and attitudes towards computers.* (Master's thesis, İnönü University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=Mir2lXQK1dkmQ9Ige3PZboaM1ssds6zvv-nMbSjOGKVBG-Q-CxnQvPINEMqGT3l_

* Atun, H., & Usta, E. (2019). The effects of programming education planned with TPACK framework on learning outcomes. *Participatory Educational Research (PER), 6* (2), 26-36. http://dx.doi.org/10.17275/per.19.10.6.2

* Aydın, H. (2021). *The effects of robotics and coding education on primary school 4th grade students' attitudes towards STEM education, basic skills and STEM career interests*. (Master's thesis, *Kırşehir Ahi Evran University).* URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=9MiDp3x86xrwjpi5-14w-ZRqufUmPCCE8-6-lwD9ROcRYHHNYwzUqQgESBtFgkG5

Balanskat, A., & Engelhardt, K. (2015). *Computing our future: Computer programming and coding - priorities, school curricula, and initiatives across Europe*. European Schoolnet. http://www.eun.org/

* Bati, K., Yetişir, M. I., Çalişkan, I., Güneş, G., & Gül Saçan, E. (2018). Teaching the concept of time: A steam-based program on computational thinking in science education. *Cogent Education*, *5*(1). https://doi.org/10.1080/2331186X.2018.1507306

Brown, Q., Mongan, W., Kusic, D., Garbarine, E., Fromm, E., & Fontecchio, A. (2008). Computer aided instruction as a vehicle for problem solving: Scratch boards in the middle years classroom. J. Lohmann (Ed.), *ASEE Annual Conference & Exposition* (pp. 9285-9300). Washington DC: American Society for Engineering Education. https://www.academia.edu/98045165/Computer_Aided_Instruction_As_A_Vehicle_For_Problem_Solving_Scratch_Boards_In_The_Middle_Years_Classroom

* Büyükkarcı, A. (2019). *The effect of 5E model enriched with coding on 4th grade mathematics achievement, retention and attitude*. (Doctoral thesis, Burdur Mehmet Akif Ersoy University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=4J_FzTwlrMCH4qBROpXPH46xi3FCz8FuGK3SrjZo9KPIUIShNt3IsfZ8JYx2gvkG

* Caballero-González, D. Y. A., & Muñoz-Repiso, A. G. V. (2020). Strengthening computational thinking and social skills through learning activities with educational robotics in early school levels. *Pixel-Bit, Revista de Medios y Educacion*, *58*, 117-142. https://doi.org/10.12795/pixelbit.75059

* Caballero-González, YA, & García-Valcárcel, A. (2020). Learning with robotics in Primary Education? A means of stimulating computational thinking. *Education in the Knowledge Society (EKS)*, *21* (15). https://doi.org/10.14201/eks.22957

* Çakır, B. (2020). The effect of coding education on students' creative problem solving and metacognitive awareness in secondary schools. (Master's thesis, Aydin Adnan Menderes University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=fl0Kw4p1rmMDotyKRdYv1Ar_43IbPj64PEytBSRJPtZ6UPyLj2KKHLxe-K-j59hY

* Çakır, R., Korkmaz, Ö., İdil, Ö., & Erdoğmuş, F. U. (2021). The effect of robotic coding education on preschoolers' problem solving and creative thinking skills. *Thinking Skills and Creativity*, *40*. https://doi.org/10.1016/j.tsc.2021.100812

* Çakır, S. (2019). *4th grade science course microscopic organisms and our environment unit, the effect of robotic coding applications on learning products.* (Master's thesis, Zonguldak Bülent Ecevit University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=npGs9H39x7G6401x51yqpHcraEx-fZuC16OGIqAMVZKq1BfjqKGbzVCV_HMxE6Qq

* Canbeldek, M. (2020). *Investigating the effects of producing children coding and robotics education program in early childhood* (Doctoral thesis, Pamukkale University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=X-M9ZoIuIoNTj2P7iY13hd4aGViCfXxYE2oq6hPNGAOIHGz4BYgvi2QJFRXIeBK8

* Cannon-Ruffo, C. M. (2020). *The Efficacy of Educational Robotics in an Integrated Stem Elementary Curriculum* (Doctoral thesis, Northern Illinois University). URL: https://search.proquest.com/openview/8ebf6a3048606826a2a341fac59a0577/1.pdf?pq-origsite=gscholar&cbl=18750&diss=y

* Çevik, M., & Şahinkayası, Y. (2021). Effect of problem-solving software developed with 5e model on success of students' states of matter. *Mustafa Kemal University Journal of the Institute of Social Sciences*, *18*(47), 92-116. https://dergipark.org.tr/en/download/article-file/1648687

* Chiazzese, G., Arrigo, M., Chifari, A., Lonati, V., & Tosto, C. (2019). Educational robotics in primary school: Measuring the development of computational thinking skills with the bebras tasks. *Informatics*, *6* (4). https://doi.org/10.3390/informatics6040043

* Çiftci, S., & Bildiren, A. (2020). The effect of coding courses on the cognitive abilities and problem-solving skills of preschool children. *Computer science education*, *30*(1), 3-21. https://doi.org/10.1080/08993408.2019.1696169

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. 2nd edn. Hillsdale, NJ: Lawrence Erlbaum Associates.

* Cruz, I. L. J. (2019). *Impact of educational robotics in promoting critical thinking skills of middle school students*. (Doctoral thesis, Southern University and A&M College). URL: https://www.proquest.com/docview/2291632045?sourcetype=dissertations%20&%20theses

* del Olmo-Muñoz, J., Cózar-Gutiérrez, R., & González-Calero, J. A. (2020). Computational thinking through unplugged activities in early years of Primary Education. *Computers & Education*, *150*, 103-832. https://doi.org/10.1016/j.compedu.2020.103832

* Diago, P. D., González-Calero, J. A., & Yáñez, D. F. (2022). Exploring the development of mental rotation and computational skills in elementary students through educational robotics. *International Journal of Child-Computer Interaction*, *32*. https://doi.org/10.1016/j.ijcci.2021.100388

Dinçer, S. (2014). *Applied Meta-Analysis in Educational Sciences* [Eğitim Bilimlerinde Uygulamalı Meta-Analiz]. Ankara: Pegem Akademi.

Fidai, A., Capraro, M. M., & Capraro, R. M. (2020). "Scratch"-ing computational thinking with Arduino: A meta-analysis. *Thinking Skills and Creativity*, *38*, 100726. https://doi.org/10.1016/j.tsc.2020.100726

* García-Valcárcel-Muñoz-Repiso, A., & Caballero-González, Y. A. (2019). Robotics to develop computational thinking in early Childhood Education. *Comunicar*, *27*(59), 63-72. https://doi.org/10.3916/C59-2019-06

* Görgülü Arı, A., & Meço, G. (2021). A new application in biology education: development and implementation of arduino-supported STEM activities. *Biology*, *10*(6), 506. https://doi.org/10.3390/biology10060506

* Gün, E. (2020). *The effect of computer science activities without computers on abstraction skills*. (Doctoral thesis, Gazi University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=Eb5EkakJlp3olBdo_wNEGURiF6DoBDi306qPMn2oOllZMUNfqtJyx72WmQ1GEc7B

* Gürkez, Ş. (2021). *The Effect of Robotic Coding Education on Middle School Students' Metacognitive Skills Awareness and Responsibility for Learning: The Case of Abilix Krypton 7*. (Doctoral thesis, Necmettin Erbakan University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=wf-FPgY-5qjHEzEoOgvMs-EFzPsOWr0CqcwLvpJ8t3_mcKp5rcASUEHWWOTgQgjq

* Hangün, M. E. (2019*). The effect of robot programming education on students' mathematics achievement, mathematics anxiety, programming self-efficacy and STEM attitude*. (Master's thesis, Fırat University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=Mir2lXQK1dkmQ9Ige3PZbqTgriK_ZmuwO_6VJ2nsAWX27bsHhIHhDQzdIehWnLR9

* Haymana, İ., & Özalp, D. (2020). The effect of robotics and coding education on creative thinking skills of primary school 4th grade students. *Istanbul Aydin University Journal of Faculty of Education*, *6*(2), 247-274. URL: https://dergipark.org.tr/en/download/article-file/1384157

International Society for Technology in Education (ISTE). (2019). *Computational Thinking Competencies.* Retrieved at 14 June, 2022 https://www.iste.org/standards/computational-thinking

* Karaahmetoğlu, K., & Korkmaz, Ö. (2019). The effect of project-based arduino educational robot applications on students' computational thinking skills and their perception of basic stem skill levels. *Participatory Educational Research*, *6*(2), 1-14. http://dx.doi.org/10.17275/per.19.8.6.2

* Kaya, M., Korkmaz, Ö., & Çakir, R. (2020). The effect of gamified robotics activities on the problem solving and the computational thinking skills of the secondary school students. *Ege Eğitim Dergisi*, *21*(1), 54-70. https://doi.org/10.12984/egeefd.588512

* Kilinç, A. (2014). *The using of robotic technology in teaching of light unit 7th grade.* (Master's thesis, Erciyes University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=sY7m19PfcL6F1NUw-cr80N-icVeux5RktxnHoas78_G3xRUKGteQv5s7c13EGIlK

Kızılkaya, G., & Aşkar, P. (2009). Developing a scale of reflective thinking skills for problem solving. *Education and Science*, *34*(154), 82-92. https://egitimvebilim.ted.org.tr/index.php/EB/article/view/550/44

* Koç, A., & Büyük, U. (2021). Effect of robotics technology in science education on scientific creativity and attitude development. *Journal of Turkish Science Education*, *18*(1), 54-72. https://doi.org/10.36681/tused.2021.52

* Kuo, W. C., & Hsu, T. C. (2020). Learning computational thinking without a computer: How computational participation happens in a computational thinking board game. *The Asia-Pacific Education Researcher*, *29*(1), 67-83. https://doi.org/10.1007/s40299-019-00479-9

Li, F., Wang, X., He, X., Cheng, L., & Wang, Y. (2022). The effectiveness of unplugged activities and programming exercises in computational thinking education: A Meta-analysis. *Education and Information Technologies*, *27*(6), 7993-8013. https://doi.org/10.1007/s10639-022-10915-x

* Lin, Y. T., Wang, M. T., & Wu, C. C. (2019). Design and implementation of interdisciplinary STEM instruction: Teaching programming by computational physics. *The Asia-Pacific Education Researcher*, *28*, 77-91. https://doi.org/10.1007/s40299-018-0415-0

Merino-Armero, J. M., González-Calero, J. A., & Cozar-Gutierrez, R. (2022). Computational thinking in K-12 education. An insight through meta-analysis. *Journal of Research on Technology in Education*, *54*(3), 410-437. https://doi.org/10.1080/15391523.2020.1870250

* Miller, J. (2019). STEM education in the primary years to support mathematical thinking: Using coding to identify mathematical structures and patterns. *Zdm Mathematics Education*, *51*(6), 915-927. https://doi.org/10.1007/s11858-019-01096-y

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., & PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA-P statement. *PLoS Medicine*, *6*(7), 1-6. https://doi.org/10.1371/journal.pmed.1000097

* Nam, K. W., Kim, H. J., & Lee, S. (2019). Connecting plans to action: The effects of a card-coded robotics curriculum and activities on Korean kindergartners. *The Asia-Pacific Education Researcher*, *28*, 387-397. https://doi.org/10.1007/s40299-019-00438-4

Noh, J., Lee, J. (2020). Effects of robotics programming on the computational thinking and creativity of elementary school students. *Education Tech Research Dev*, 68, 463–484. https://doi.org/10.1007/s11423-019-09708-w

Numanoğlu, M., & Keser, H. (2017). Robot usage in programming teaching - mBot example. *Bartın University Journal of Faculty of Education, 6*(2), 497. https://doi.org/10.14686/buefad.306198

* Okkesim, B. (2014). *Robotics applications in science and technology education.* (Master's thesis, Erciyes University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=gyLHMouPes-CvnhRcjQsKcUrp56uQFmhkfxhhnyuRne42bwOuByKEHeCFS-K-Coy

* Oluk, A., Korkmaz, Ö., & Oluk, H. A. (2018). The effect of Scratch on 5th grade students' algorithm development and computational thinking skills. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *9*(1), 54-71. https://dergipark.org.tr/tr/download/article-file/432160

* Özdoğru, E. (2013). *The effect of Lego program-based science and technology education for physical phenomena learning domain on students' academic achievement, science process skills and attitudes towards science and technology course.* (Master's thesis, Dokuz Eylül University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=iTkOhwevEenJZ3onUvs52oFv5EuvQzodV4JdcFL0xAzM8PeWObDxfpLAYFTEk5Bx

Ramazanoğlu, M. (2021). The effect of robotic coding applications on attitudes of the secondary school students towards computers and their perceptions of self-efficacy regarding computational thinking skills. *Turkish Journal of Social Research, 25*(1), 163-174. https://dergipark.org.tr/tr/download/article-file/1101111

* Relkin, E., de Ruiter, L. E., & Bers, M. U. (2021). Learning to code and the acquisition of computational thinking by young children. *Computers & education*, *169*, 104222. https://doi.org/10.1016/j.compedu.2021.104222

Resnick, M., & Silverman, B. (2005). Some reflections on designing construction kits for kids. In M. Eisenberg, A. Elsenberg (Ed.), *Proceedings of the 2005 Conference on Interaction Design and Children.* (pp. 117-122). Boulder, Colorado, USA: Acm. https://doi.org/10.1145/1109540.1109556

* Sade, A. (2020). *The effect of coding instruction on 6th grade students' computer thinking skills, mathematics anxiety perceptions and problem-solving perceptions.* (Master's thesis, Mersin University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=fl0Kw4p1rmMDotyKRdYv1IhRYtojQQNr1b_wv9Ww4TEhHNF40mcO-Sr8tkTPyPlq

* Saez-Lopez, J. M. (2021). Introducing robotics and block programming in elementary education. *Revista Iberoamericana de Educación a Distancia*, *24*(1), 95-113. http://dx.doi.org/10.5944/ried.24.1.27649

* Sáez-López, J. M., & Sevillano-García, M. L. (2017). Sensors, programming and devices in Art Education sessions. One case in the context of primary education. *Culture and Education*, *29*(2), 350-384. https://doi.org/10.1080/11356405.2017.1305075

* Sáez-López, J. M., Román-González, M., & Vázquez-Cano, E. (2016). Visual programming languages integrated across the curriculum in elementary school: A two-year case study using "Scratch" in five schools. *Computers & Education*, *97*, 129-141. https://doi.org/10.1016/j.compedu.2016.03.003

* Sáez-López, J. M., Sevillano-García, M. L., & Vazquez-Cano, E. (2019). The effect of programming on primary school students' mathematical and scientific understanding: educational use of mBot. *Educational Technology Research and Development*, *67*(6), 1405-1425. https://doi.org/10.1007/s11423-019-09648-5

* Sanders, T. S. (2020). *A Causal-Comparative Study of the Relationship between Fifth-Grade Girls' Mathematics Achievement and Participation in a Code-Based Robotics Program* (Doctoral dissertation, Northcentral University).URL: https://www.proquest.com/docview/2378054479?pq-origsite=gscholar&fromopenview=true&sourcetype=Dissertations%20&%20Theses

* Somuncu, B. (2021). *The effect of coding training on the mathematical reasoning skills of preschool children.* (Master's thesis, Çukurova University) URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=wf-FPgY-5qjHEzEoOgvMs9g18xbzv4lSimPyjf-Xf3ucuTuv3hHrFy3HQ0cbTE0F

* Soykan, F., & Kanbul, S. (2018). Analysing K12 students' self-efficacy regarding coding education. *TEM Journal*, *7*(1), 182. https://doi.org/10.18421/TEM71-22

* Sun, L., Hu, L., & Zhou, D. (2021). Improving 7th-graders' computational thinking skills through unplugged programming activities: A study on the influence of multiple factors. *Thinking Skills and Creativity*, *42*, 100926. https://doi.org/10.1016/j.tsc.2021.100926

Sun, L., Hu, L., & Zhou, D. (2021b). Which way of design programming activities is more effective to promote K-12 students' computational thinking skills? A meta-analysis. *Journal of Computer Assisted Learning*, *37*(4), 1048-1062. https://doi.org/10.1111/jcal.12545

* Şimşek, K. (2019). *Investigation of the effects of robotic coding application on science achievement and scientific process skills of 6th grade students in science course matter and heat unit* (Doctoral thesis, Marmara Universitesi). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=aEzj_IdWAsjiSAfK3qwrBlS9XLUUeR9cFUBBdDysbrw2umu_vMQNvLXtJLdrs70c

Thalheimer, W., & Cook, S. (2002). How to calculate effect sizes from published research: A simplified methodology. *Work-Learning Research*, 1(9). https://paulogentil.com/pdf/How%20to%20calculate%20effect%20sizes%20from%20published%20research%20-%20a%20simplified%20methodology.pdf

* Tiryaki, A. (2020). *The effect of robotic coding education on programming self-efficacy levels and creative thinking skills of secondary school students.* (Master's thesis, *Mustafa Kemal University).* URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=fl0Kw4p1rmMDotyKRdYv1LPK6zc4lRg_bTpCyBFkFxd339oXV0-mhlyYkhvew3Nr

* Üngör, Y. E., Korkmaz, Ö., Çakir, R., & Erdoğmuş, F. U. (2020). Flowchart destekli proje tabanlı algoritma eğitiminin etkililiği. *Turkish Journal of Primary Education*, *5*(2), 98-118. URL: https://dergipark.org.tr/en/download/article-file/1206928

* Ünsal, İ. (2020). *The effect of the block based programmed activities over the computational thinking ability and the perception exercise of 2nd classes primary school students*. (Master's thesis, Sakarya University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=fl0Kw4p1rmMDotyKRdYv1LRIqmnjIeupqpxGncWFqLvqxyQZlby9ba5UjZ0_jF94

* Uşengül, L. (2019). *The effect of Lego Wedo2.0 education on the academic achievement, attitudes, and computational thinking skills of students in science classes.* (Master's thesis, Fırat University). URL: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=jNRDC1RLfVd4_T7x7ZXmmTNMAMpsjm-5_yBO5SxYb4befqH1Rs4gz6lcszFaEJsz

Wang, X., Chan, K. K., Li, Q., & Leung, S. O. (2024). Do 3–8 years old children benefit from computational thinking development? A meta-analysis. *Journal of Educational Computing Research*, online first. https://doi.org/10.1177/07356331241236744

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33- 35. https://dl.acm.org/doi/pdf/10.1145/1118178.1118215

* Wu, T. T., & Chen, J. M. (2022). Combining Webduino programming with situated learning to promote computational thinking, motivation, and satisfaction among high school students. *Journal of Educational Computing Research, 60(*3), 631-660. https://doi.org/10.1177/07356331211039961

* Yolcu, V. (2018). */ The effect of using robotics on academic success, computational thinking skills and transfer of learning in programming education*. (Master's thesis, Süleyman Demirel University). https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=MzP7PYssFqdb3WIjlroAkZtvhcvVC25RhJ2m-YBdY0bkJdNx46AWg7iEd1vDXHSC

* Zha, S., Morrow, D. A., Curtis, J., & Mitchell, S. (2021). Learning culture and computational thinking in a Spanish course: A development model. *Journal of Educational Computing Research*, *59*(5), 844-869. http://dx.doi.org/10.1177/0735633120978530