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The Effect of Educational Robotic Applications on Academic Achievement: A Meta-Analytic and Meta-Thematic Study

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Abstract

In this study, the effect of educational robotic applications on academic achievement was examined using meta-analytic and meta-thematic methods. The CMA program was used in the analysis of the quantitative data in the study, and since it was determined that there was heterogeneity between the studies. As a result of the quantitative findings of the study, it was determined that educational robotic applications had a strong positive effect on the academic achievement of the students (Hedge's g = 0.822). According to the results of the research, it was concluded that it had the most significant effect on students' academic success in the fields of science (Hedge's g = 1.134) and algorithm (Hedge's g = 1.121) according to the courses, and at the secondary school level (g = 0874, Qbetween = 1.608, p = 0.000) has been reached. As a result of the qualitative findings obtained from the study, it was determined that educational robotic applications contributed positively to students' learning in many cognitive, affective, and social aspects such as classroom participation, active learning, motivation, cooperation, and communication. According to the results of the research, it can be said that educational robotic environments have many positive effects such as relating to real life, learning by doing and experiencing, provides concrete experiences, active participation, but there are problems such as technical problems, time consuming and making learning difficult.

Keywords: Educational Robotics, meta-analysis, meta-thematic, academic achievement

Introduction

There is no doubt that developments in science and technology have affected the educational environment as well as all other fields, and accordingly, a transformation has started in the educational environment. (Uşun, 2004; Aslan, Göksu and Atıcı, 2016). In addition to the transformation in education, the roles of students and teachers have also been realigned. In the literature, definitions such as net generation (Tapscott, 1998), digital native (Prensky, 2001), and millennium learners (Oblinger and Oblinger, 2005) were made for today's students and the most distinctive characteristic of these students was their extensive use of technology (Tapscott, 1998; Prensky, 2001; Oblinger and Oblinger, 2005). In addition, in conjunction with advances in science and technology, some characteristics such as survival skills developed by Wagner (2008) and 21st century skills developed by organizations such as Partnership for 21st Century Skills (P21) and International Society for Technology in Education (ISTE) were identified, and it was stated that students should have these skills in order to be successful. In this context, when the literature was examined, there were studies showing that educational robotic applications improved students' 21st century skills (Atasoy, Yüksel and Özdemir, 2018; Negrini and Giang, 2019; Erdoğan, Toy and Kurt, 2020).

Robotic applications have emerged as an interdisciplinary tool (Alimisis, 2013) that arouses students' interest and curiosity, offers entertaining activities (Eguchi, 2010), and supports learning by improving their cognitive and social skills. Turkish Language Society (2020) defines robot as “an automatic vehicle that can be made to perform various duties with magnetism in order to complete a certain job”. Although robotics has been used in engineering for a long time, it emerged as a new didactic in educational environment by getting prevalent every day, providing lower cost equipment for educational applications, being an effective learning tool providing teachers easily accessible learning opportunities even though they did not have much technical knowledge, and being adaptable to the curriculum from pre-school to university (Menegatti and Moro, 2010).

LOGO studies developed by Papert can be considered as the pioneer of robotics applications in education (Botelho, Braz and Rodrigues, 2012). With the use of personal computers in the late 1970s, LOGO was taught students to teach them how to write computer programs. (Resnick, 2012). Papert (1999) describes LOGO as a "a programming language and educational philosophy" and notes that there is more to LOGO than to constructivist education. The intellectual foundations of LOGO are based on artificial intelligence, mathematical logic, and developmental psychology (LOGO, 2020). According to Papert, a person learns by structuring the knowledge in his/her mind, and to do this, he/she must learn by doing. Papert's constructionism theory is one of the most important advances emphasizing the importance of using robotics and technology in education (Harel and Papert, 1990). Following Piaget's theory of constructivism, Papert proposed that the best way to build knowledge is to actively introduce a shareable product (Stager, 2016). According to Papert (1999), constructivism stresses how knowledge is learned and how it should be taught, while constructionism also includes what the citizens of the future should know, and technology is the environment of both knowledge and of constructing things. Getting information about a subject from a teacher or a book, or on the internet is only one part of the education, while the other part is doing and constructing. Today, because of the prevalent use of robotic activities in education, many robot kits have been introduced (Numanoğlu and Keser, 2017).

Educational robotic applications have many contributions to education. According to Catlin and Blamires (2010), educational robotic applications offer students the opportunities of engagement, sustainable learning, and personalization in education. According to Kabatova and Pekárová (2010), educational robotic applications provide students with social skills such as collaboration, group work and responsibility and they offer the opportunity to learn by doing and to try/test and correct mistakes while learning. Educational robotic applications offer students the opportunity to learn concepts in a broader range (Botelho, Braz and Rodrigues, 2012). When the literature was examined, it was seen that studies about educational robotic applications have been conducted in several fields such as programming (Numanoğlu and Keser, 2017; Durak and Yılmaz, 2018; Yükseltürk and Curaoğlu, 2018; Çelik, 2019, Huang, Yang and Cheng, 2013) mathematics (Kazez, 2015;Hangün, 2019), science and technology (Şenol and Büyük, 2015; Koç and Böyük, 2013; Özdoğru, 2013; Erdoğan, Kurt and Toy, 2020; Yenikalaycı and Harman, 2020, Akarca, 2019), STEM (Dönmez, 2017;Ching et. al, 2019), coding (Kasalak, 2017; Erten, 2019), music (Karademir, 2018, Özkandemir, 2019), and their effects on some variables such as motivation (Aydın, 2019; Chin, Hong and Chen,2014; Akman Selçuk, 2019, Hong vd., 2016), TPACK skills (Avcı, 2017;), problem solving skills (Dizman, 2018; Avcı, 2017; Kıran, 2018; Barak ve Assal, 2018; Li et. Al., 2014; Silik, 2016), scientific creativity (Avcı, 2017), metacognitive awareness (Dizman, 2018), 21st century skills (Erdoğan, Kurt ve Toy, 2020; Bal, 2019), computational thinking (Bal, 2019; Berland and Wilensky, 2015; Kaya, Korkmaz and Çakır, 2020), critical thinking (Çelik, 2019) has been investigated. However, it has been determined that there were no meta-analysis and meta-thematic studies that evaluated the effects of educational robotic applications on academic achievement with qualitative and quantitative methods. Moreover, it has been observed that scholarly research on educational robotic applications have primarily been undertaken in the fields of science and no studies have been conducted in areas such as social studies and Turkish education. In essence, it is assumed that this study would add to the field by creating a more holistic perspective, qualitatively and quantitatively, regarding the effect of educational robotic applications on learning.

In this study, it was aimed to determine the effect of educational robotic applications on students' academic achievement. Therefore, the research questions of the study were established as:

- How is the effect level of educational robotic applications on students' academic achievement?
- Is there a significant difference in the effect level of educational robotic applications on the academic achievement of students according to the variables of education level and subject area?
- What is the effect of educational robotic applications on learning within the framework of meta-thematic analysis?

Method

Research Design

This study was conducted using mixed method design to determine the effect of educational robotic applications on learning. Meta-analysis method was used in combining quantitative study results, and meta-thematic analysis method was used in combining qualitative study results.

In this study, meta-analysis was used to determine the effect level of educational robotic applications on students' academic achievement. Meta-analysis is "*grouping similar studies on a subject, theme or field of study under certain criteria and interpreting the quantitative findings of these studies by combining them*" (Dinçer, 2014). Meta-analysis is a reproducible and more rigorous cumulative approach based on summarizing quantitative studies (Rosenthal and Di Matteo, 2002) and a statistical application that associates the consequence of more than one study that considered to be combined (Egger, Smith, & Phillips, 1997; Thompson and Sharp, 1999; Petitti, 2001). According to Bakioğlu and Göktaş (2018), it is the process of integrating reinterpreting and obtaining new results from the knowledge gained as a result of various analyses with special methods. It summarizes the quantitative study results by combining them and enables us to synthesize the results obtained from different studies by combining different study results and creating a more measurable common value called effect size (Littell, Corcoran and Pillai, 2008).

In the study, meta-thematic analysis was used to draw a general framework for qualitative data and to establish a more holistic perspective. Meta-thematic analysis enables researchers to interpret the results of qualitative studies based on document analysis by re-creating themes and codes, and to develop a more holistic interpretation of the results of these studies (Batdı, 2019). Meta-thematic analysis includes the consolidation and compilation of the views of the participants of some selected qualitative studies (Batdı, 2017). In this context, document analysis was performed first to create the themes and codes related to the qualitative studies examined. Document analysis is the analysis of materials that provide information about the problem (Yıldırım and Şimşek, 2006).

Data Collection

Within the scope of the research problem, the databases of Science Direct, Google Scholar, ERIC, ProQuest Proquest Dissertation & Theses, YÖK Thesis center, ULAKBİM databases are scanned with the keywords "educational robotics" AND "achievement", "performance" between 25.09.2020-30.10.2020. Studies included in the criteria were included in the study. Working within these criteria:

- It was published in 2010-2020,
- Having an article published in a refereed journal or a master's / doctoral thesis,
- It has been published in English or Turkish,
- It was made with an experimental design with control group,
- Providing the necessary information (Mean (X), Standard Deviation (Ss.), Sample Sizes (n)) for meta-analysis,

- The study is for educational purposes.

The process regarding the flow of the study is shown in the PRISMA diagram. PRISMA diagram is a good solution to show the flow of work (Stovold, Beecher, Foxlee & Noel-Storr, 2014).

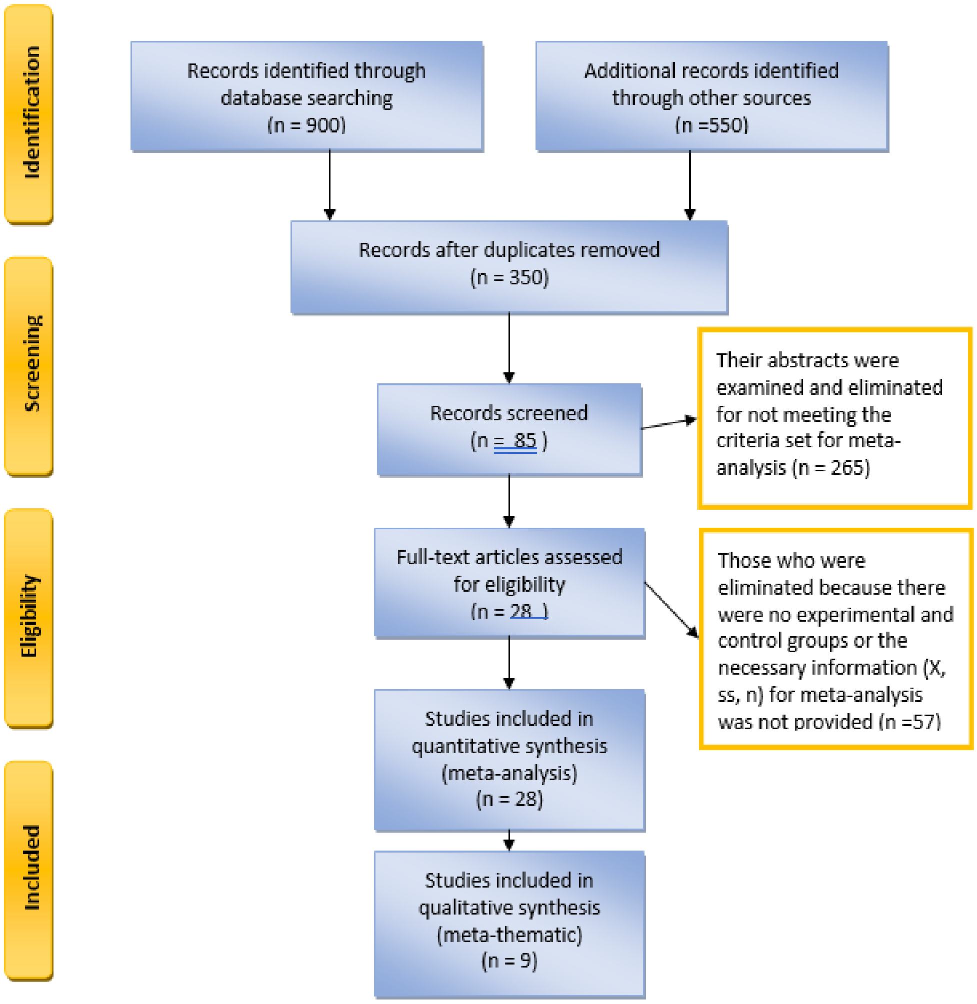

Figure1. PRISMA Diagram (Stovold, Beecher, Foxlee & Noel-Storr, 2014).)

Within the scope of this study, a total of 900 studies were reached with keywords, 550 studies were eliminated because they were the same. The abstracts of the remaining 350 studies were examined and 265 of them were eliminated because they did not meet the criteria of being published between 2010 and 2020, being published in a master's thesis or peer-reviewed journals, and being published in English or Turkish. The full text of the remaining 85 studies were examined and 57 studies were eliminated and 28 studies were included in the meta-analysis because the necessary information was not given to find an experimental-control group and to calculate the effect size. For meta-thematic analysis, 9 mixed studies with qualitative dimensions were selected from 28 studies included in the meta-analysis.

Coding of Studies

In order to enter the information about the studies included in the meta-analysis in line with the criteria determined in this study, a coding form was created first. The first part of this coding form consists of information such as author information, publication year, course area, education level of the study. In the second part of the coding form, the necessary information (Mean (X), Standard Deviation (Ss.), Sample Sizes (n)) to calculate the effect size of the experimental and control groups included in the studies included in the matte-analysis was entered. After coding, the information entered by each author was compared according to the formula [(consensus / (consensus + disagreement) / 100] (Miles & Huberman, 1994) and calculated as 90%. Accordingly, it can be said that the study is reliable. Table 1 contains demographics of the studies included in the meta-analysis.

Table 1. Information regarding the studies included in the meta-analysis study

		f
Type of the study	Master's thesis	17
	Doctoral dissertation	2
	Journal article	9
	Elementary school	6
	Middle school	15
	High school	4
	University	3

In this study, a qualitative study was conducted among the studies selected for the meta-analysis study, and 9 studies were selected for meta-thematic analysis on the perceptions and opinions of the participants on educational robotic applications. The literature review reveals that thematic research is usually performed in three steps (Thomas and Harden, 2008; Vassie, Smitth and Leedham-Green, 2020):

1. Reviewing sufficient number of articles for the researcher,
2. Creating theme and coding tree and performing descriptive analysis of main lines,
3. Interpretation of data

In this study, first, the themes and codes were created by subjecting the views of the participants in the studies chosen for meta-thematic analysis to content analysis. Content analysis; coding of data and creating themes and editing and interpreting the created code and themes. In short, content analysis is the process of classifying similar data on certain topics and combining and interpreting them around themes (Yıldırım and Şimşek, 2006). Participant views in the studies included in the meta-thematic analysis were re-processed by the researchers into the MAXQDA program, and similar ones were classified and themes and codes were created in this framework. The themes and codes created within the scope of the meta-thematic analysis are based on the literature review on educational robotic applications. The data regarding the opinions of the participants in the studies selected for meta-thematic analysis were given as direct quotation without changing. Thesis studies are coded with "T", article studies with "A". For example, in the quote code "T10-K5", "T" indicates thesis, "A" indicates article; "10" indicates the code of the study. "K5" indicates the position of the quote on the coding page in the MAXQDA program.

Reliability of the Study

For the reliability of the study, the data were entered separately by the researchers and then compared. According to the formula of "(Consensus / [Consensus + Disagreement])" suggested by Miles and Huberman (1994), the coefficient of agreement between coders was determined as 90%. In order for the study to be considered reliable, this harmony must be at least 70% (Yıldırım & Şimşek, 2006). According to this result, it can be said that the reliability level of the study is high.

Findings regarding publication bias

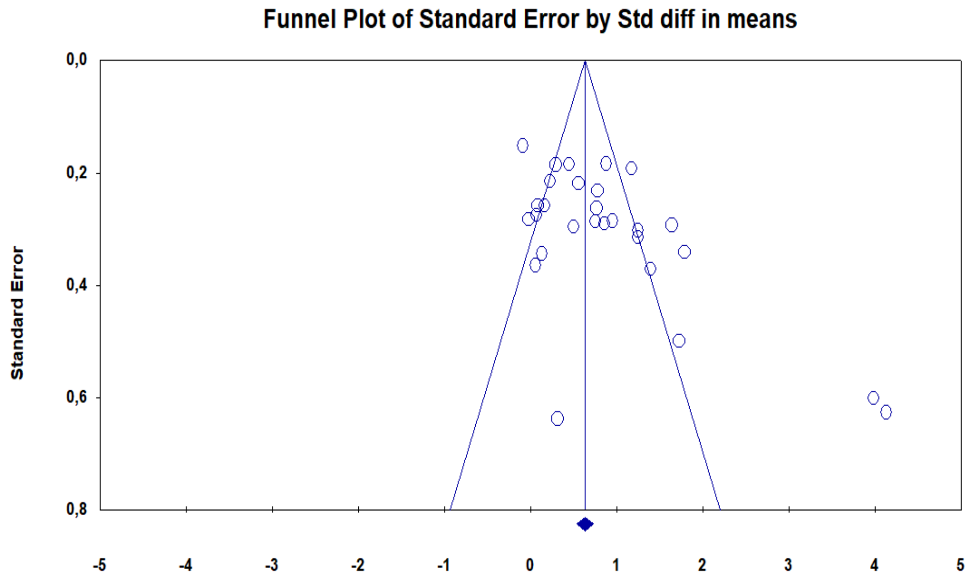

Figure 2. Funnel Plot Regarding Publication Bias

Figure 2 indicates that the studies are distributed symmetrically in the funnel plot and are generally gathered at the top of the funnel. While the studies in the upper part of the funnel represent studies with large sampling (Egger, Smith and Phillips, 1997), the symmetry of the studies indicates that there is no publication bias (Begg, 1994; Sutton, 2009).

Table 2. Publication Bias

Z-value for observed studies	14.3
p-value for observed Studies	0.0
Alpha	0.05
Directions	2
Z for alpha	1.95
Number of observed studies	28
Number of missing studies that would bring p-value to> alpha	1484

Rosenthal (1991) expressed that when the safe N number consisting of k studies is N> 5k + 10, the study will be far from publication bias. (Rosenthal & DiMatteo, 2001). According to this theory, the size of the safe N number compared to the number of studies included in the meta-analysis indicates that the study does not have publication bias. Based on this result, it can be claimed that this study (1484> 5.28 + 10) is not publication bias.

Data Analysis

In this study, CMA program was used to calculate the effect size. The data included in the studies included in the meta-analysis were processed separately in the coding form by the researchers and then compared.

Funnel plot and Rosenthal's Safe N Theory methods were used to determine whether there is publication bias. The funnel plot starts from the idea that as the sample number of the studies included in the meta-analysis increases, the effect size calculation will be more accurate. In this graph, studies with small sample numbers are collected under the graph, studies with large samples are collected at the top of the graph, and the symmetry of the graph indicates that there is no publication bias (Egger, Smith Phillips, 1997).

In the study, heterogeneity test was conducted to decide the test to be selected for effect size calculation and p, Q and I^2 values were examined for this. The value of the Q value in the X^2 table was determined and compared with the Q value found, then it was determined whether a heterogeneous structure existed between the studies by checking the I^2 value. Because heterogeneity in meta-analysis studies indicates the diversity of studies included in meta-analysis (Higgins & Thompson, 2002).

For the calculation of the effects sizes, Hedge's g formula was employed. Effect size is a standard form of mean difference (Hedges & Olkin, 2014). The classification proposed by Thalheimer and Cook (2002) was referred in the effect size classification.

Effect size ≤0.15	Negligible
0.15 < Effect size ≤ 0.40	Small
0.40 < Effect size ≤0.75	Medium
0.75 < Effect size ≤1.10	Large
1.10 < Effect size ≤1.45	Very large
1.45 < Effect size	Huge

Findings

Findings regarding the meta-analysis

Since there was heterogeneity among the studies included in the meta-analysis, the random effects model was used in calculating the overall effect size (Table 3).

Table 3. Effect Size Regarding Educational Robotic Applications

Model Type	n	Z	p	Q	g	I^2	% 95 confidence interval	
							Lower Limit	Upper Limit
FEM	28	12.783	0.000	167.068	0.629	83.839	0.533	0.726
REM	28	6.450	0.000	167.068	0.822	83.839	0.572	1.072

In a meta-analysis study, in order to decide by which model the effect size will be calculated, it should first be tested if there is heterogeneity between studies. Based on the information in Table 3, it was concluded that the studies included in the meta-analysis were heterogeneous (Q=167.068, p<.05) and the level of heterogeneity (I^2) was 83 %. As shown by Cooper, Hedges and Valentin (2000), an I^2 value above 75% suggests that the degree of heterogeneity is high. In cases of heterogeneity among the studies included in the meta-analysis, random effects model is used in the calculation of effect size (Dinçer, 2014). In this study, the overall effect size was calculated as (Hedge's g = 0.822) and there was a positive significant difference between studies (Z = 6.450, p = 0.000). This value is a large effect according to Thalheimer and Cook (2002).

Table 4

The Effect of Educational Robotic Applications on Academic Achievement Based on Moderator Variables

	Model			% 95 Confidence Intervaş		Degree of freedom	Heterogeneity Test	
	Random Effects Model	N	Hedge's g	Lower Limit	Upper Limit		$Q_{between}$	p
Subject	Algorithm	2	1.121	0.252	1.990	21	21.548	0.000
	Science	8	1.134	0501	1766			
	Physics	3	0.097	-0288	0481			
	Coding	3	0.438	-0.169	1044			
	Mathematics	5	0966	0.304	1687			
	Programming	6	0.762	0.337	1.187			
	Foreign Language	1	0841	0.281	1.401			
School Level	Elementary School	6	0.868	0.383	0.788	3	1.608	0.000
	Middle School	15	0.874	0.546	0.791			
	High School	4	0.660	0.229	0.872			
	University	3	0.615	0.159	0.802			

In Table 4, the effect of educational robotic applications on students' academic achievement by subject area was examined and it has been determined that subject area changes academic achievement. The overall effect size has created a significant difference in subjects of Science (Hedge's g = 1.134) and Algorithm (Hedge's g = 1.121). These results were very large according to Thalheimer and Cook (2002). For calculating the effect sizes based on subject area, the critical value (41.401, 95% significance level) from the X^2 table was compared and heterogeneity (Qbetween = 21.548, df = 21, P = 0.000) was found among the studies, therefore random effects model was used.

Based on the results in Table 4, the effect of educational robotic applications on academic achievement based on education level was examined and it was concluded that there was a significant difference in favor of the middle school level (g = 0874, $Q_{between}$ = 1.608, p = 0.000). This value seems to indicate a large effect according to Thalheimer and Cook (2002). For the calculation of effect size by education level, it was compared with the critical value (12.838) from the X^2 table at the 95% significance level, and it was found that there was heterogeneity (Qbetween = 1.608, df = 3, P = 0.000) between the studies, therefore random effects model was employed for calculating the effect sizes.

Findings regarding the meta-thematic review

Figure 3. General characteristics of educational robotic applications

When Figure 3 was reviewed, it was observed that among the general features of educational robotic applications, there were codes such as "relating to real life", "learning by doing and experiencing", "provides concrete experiences", "active participation". When creating these codes, following excerpts were effective:

In T6-K8 *"... when solving problems with the robot we added new things, used pieces. For example, the problems in our daily life, because we apply them, we can solve them briefly, technically",*

In T18-K13 "*We learned better by applying the abstract concepts we learned in programming to how things like loops and conditions actually work in sensors in the robot. We learned how to use robots in real life especially in project applications",*

T5-K12 *" At least we put it into practice and used examples from daily life. It is not just in theory; we have seen it with its Application. That is why I think it is useful",*

T5-K52 *"... I saw that coding can also be learned through a tool. When I compare it with other coding and programming courses, I think it is more understandable and easier to learn through a tool".*

Among general characteristics of educational robotic applications, other prominent codes were "increases motivation", "allows for different activities", "developing a different perspective", and "trial-correction possibility". The following excerpts were effective in creating these codes:

T5-K41 "*I think that seeing what we were doing in practice with the robot's movement motivated us in a good way”*,

T6-K37 " *Normally we may not want to attend the last lesson at all. But since we are going to build robots, we are usually willing to come. The whole class is like this*",

T9-K11 "... *we built a robot, tried and run our algorithm. We realized the accuracy of the algorithm we created when we examined the robot",*

T6-K28 *"After making a mistake we were rushing to fix it right away*",

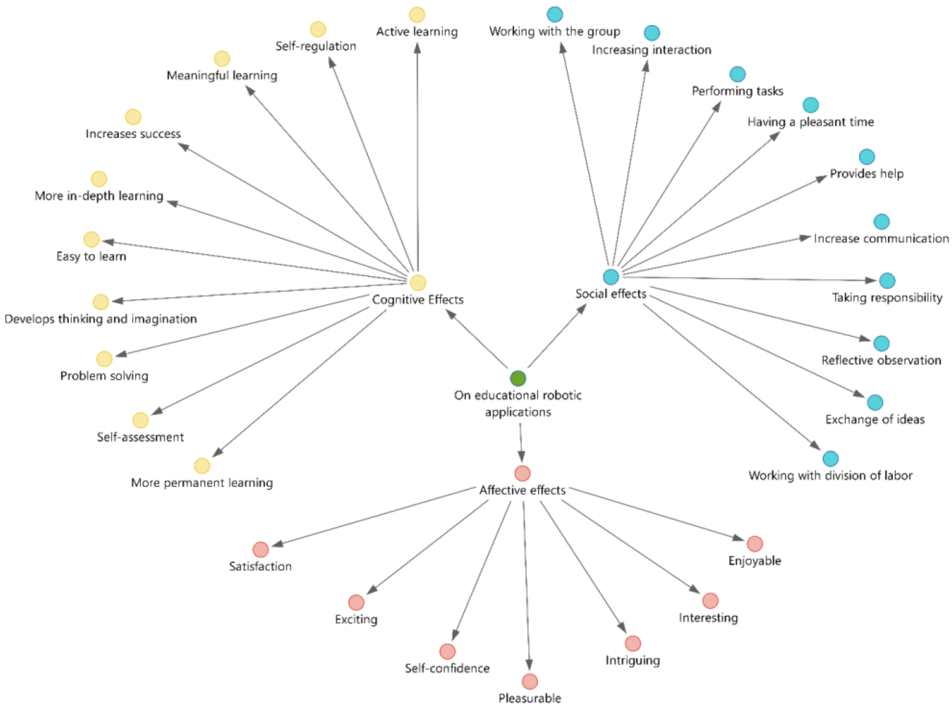

Figure 4. Cognitive, affective and social effects of educational robotic applications

When Figure 4 was examined, it was seen that codes such as "increases success", "easy to learn", "more in-depth learning", "more permanent learning" were created regarding the cognitive effects of educational robotic applications. The following excerpts were effective in creating these codes:

T18-K4 " *I think my course performance has increased. We've never heard of these concepts before, but here we had the opportunity to learn and apply these concepts, which we had difficulty understanding in the past, with robots",*

T11-K124 *"robotics influence to take higher level math*",

T18-K13 " *We learned better by applying the abstract concepts we learned in programming to how things like loops and conditions actually work in sensors in the robot",* T9-K15 *" I think I understand the algorithm we developed better by trying it on the robot",*

T6-K1 *"We* both understood better and learned how to make algorithms faster"

T5-K54 "*I remembered it more as I practically saw how the codes work*",

T12-K46 "We *did an activity, wrote and learned. It was shown from the slide, we built the robot, we learned them, we learned more examples in daily life and we learned by reinforcing what we learned, I think it is better in this respect ...*".

When Figure 4 is investigated, it was seen that other codes related to educational robotic applications were "self-regulation", "self-evaluation" and "develops thinking and imagination". The following excerpts were effective in creating these codes:

T18-K3 "I *began to realize power of my own thinking. I felt my power to think in differently increased and improved* ",

T6-K52 *"At first, I didn't understand the algorithm in the lesson. After the robot work I got it, I'm even better* ",

T9-K4 "We *first created an algorithm to do the tasks for that week. We created and program robotics according to the algorithm we created",*

When Figure 4 was examined, it was seen that codes such as "pleasurable", "interesting", "enjoyable", "satisfaction" were created for the affective effects of educational robotic applications. The following excerpts were effective in creating these codes: T12-K3 "*…Robotics is a really interesting educational tool …*",

T12-K5 "*"… We understand the lesson in a fun and instructive way …*",

T12-K5 "*"… We enjoyed doing the activities, for example …*",

T10-K3 " *I think the robotics lesson is very good. When I first saw the robots it felt boring, but when I learned about them, I realized that it was a lot of fun.* ",

T9-K12 "It *was great watching the robot work, because we did it* ",

T6-K38 "Thanks *to the robot, my curiosity increased. It was boring before. Thanks to the robot it became nice and fun* ". When Figure 3 was examined, it was seen that the other themes related to affective effects consisted of "intriguing", "self-confidence" and "self-knowledge" codes. The following excerpts were effective in creating these codes:

T18-K5 "*I was wondering how computer and robotic systems work. I was doing research at home for this. It supported me very much in this respect. I found answers to most of my questions*",

T12-K9 "I *felt more like a researcher and started to see myself that way. I felt like a researcher, it was like schools in Europe …", "…I was afraid to take tests, but now I think I can solve any question related to these issues…"*,

T10-K6 "*I have a lot of fun in robot lessons. I always wonder what we will do. Seeing the robot do something makes you happy and curious*".

When Figure 4 was reviewed, it was detected that there were codes such as "communication", "interaction", "cooperation", "working with the group" among the social effects of educational robotic applications. The following excerpts were effective in creating these codes:

T9-K19 "*When we do it with a group, everybody says their opinion and we reach a solution faster. I could have had difficulties alone. My friends correct me right away*",

T6-K14 "*Usually we talk as a whole class every day about the papers you give …*",

T16-K15 "*Since we do it as a group, everyone has an opinion, so the group work is more advantageous*",

T6-K26 "*It would never work if everybody did what they had in their mind* ",

T5-K37 "B*ecause we worked as a group, we covered each other's shortcomings*". When Figure 4 was examined, it was seen that codes such as "responsibility", "exchange of ideas", "solidarity" and "getting to know your friends better" regarding the theme of social effects were also created. The following excerpts were effective in creating these codes:

T6-K12 "Everyone *is saying their general opinion, we can continue accordingly …*",

T6 K21 "We *got to know our groupmates. We understood how we can work with them ",*

T6-K21 "everyone had a duty, I mean, it wouldn't be without taking responsibility".

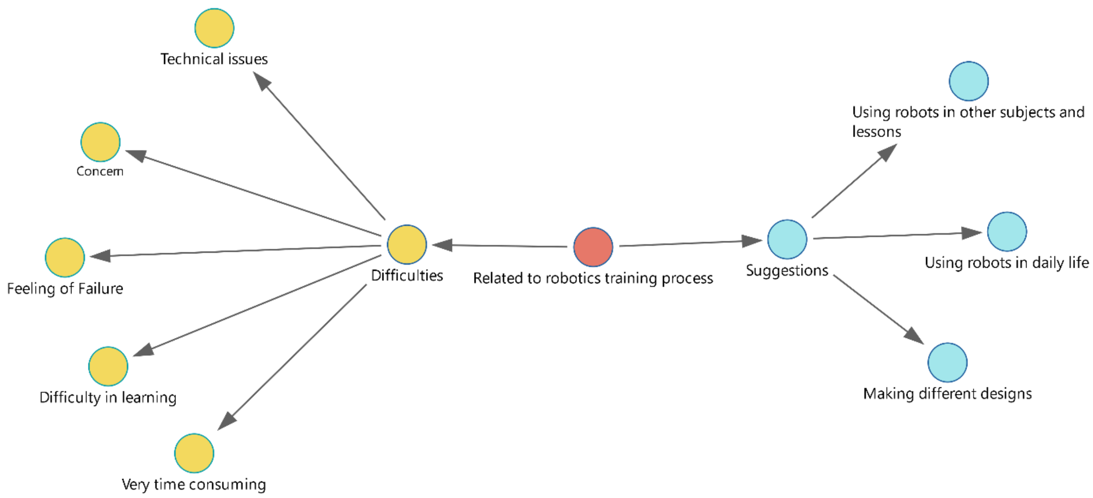

Figure 5. Challenges encountered in the educational robotics training process and recommendations

When Figure 5 was investigated, it was observed that the codes of "concern", "technical issues", "very time consuming", " difficulty in learning " and "feeling of failure" were created in the theme of difficulties related to the robotic education process. The following excerpts were effective in creating these codes:

T18-K25 "I *had a hard time testing the light sensor on the robot. When the environment is bright the sensor barely worked*", T9 K46 “I *don't think legos will be useful in daily life. Creating an algorithm is very difficult*",

T5 K21 “I *did a research when I first heard about it… I thought as if it would be difficult. I was afraid that I could not do it. I did not have any knowledge either*",

T5 K45 “Fitting *LEGO® pieces was difficult. They were small and we could not find their place. The first robot design was a challenge for us*".

In the theme of suggestions regarding educational robotic applications in Figure 4, codes of "making different designs", "using robots in other subjects and lessons" and "using robots in daily life" were created. The following excerpts were effective in creating these codes:

T12-K60 *"… I think the use of robots would go well with the pulleys in physics. …”*,

T12-K70 *“…We can design many robots like these, and they all understand our lessons separately and keep the topics memorable…”*, T6-K21 " *If robots are built to help people, for example, there are people with disabilities, they can help disabled people, or they can help women in the kitchen*",

T12-K65 "“… *Science means always learning by doing experiments, I think it is learned more by experimenting and examining, so I think robots should be used in lessons…”*.

Conclusion and Discussion

The current study tried to determine the effect of educational robotic applications on learning by qualitative and quantitative methods. In this context, regarding the quantitative findings of the study, a total of 28 studies including 19 thesis and 9 articles were analyzed by meta-analysis method. In the meta-analysis, first, funnel plot and Rosenthal N Theory methods were used to test whether there was publication bias among the selected studies. In the funnel plot, it was observed that the studies were generally collected at the upper part of the funnel and showed a symmetrical distribution which was an indication of no publication bias. In addition, according to the Rosenthal N Theory, it was reported that findings of the meta-analysis would be very high if N> 5k + 10. In this context, since (1484> 5.28 + 10), it might be said that the study did not show publication bias. The heterogeneity test was performed to determine the method to calculate the effect size of the studies included in the meta-analysis, and it was determined that there was a heterogeneous structure among the studies (Q = 167.068, p <.05), and the heterogeneity level between studies (I^2) was determined as 83%. For this reason, random effects model was employed for calculating the effect sizes.

According to the study, the overall effect size was calculated as (Hedge's g = 0.822) and there was a positive significant difference between studies (Z = 6.450, p = 0.000). This value is a large effect according to Thalheimer and Cook (2002) indicating that educational robotic applications have a positive and wide effect on academic achievement in favor of the experimental group. In the meta-analysis study of 12 studies on educational robotic applications by Athanasiou, Mikropoulos and Mavridis (2018), it was observed that educational robotic applications positively affected academic achievement. In addition, this result was similar to Barker and Ansorge (2007), Huang, Yang and Cheng (2013) Kılınç (2014), Li et al. (2016), Çukurbaşı (2016), Hong et al. (2016), Pirrone et al. (2018), Badeleh (2019), Ulloa-Higuera (2019), Altakhayneh (2020) and Gündoğdu (2020). On the other hand, in the studies conducted by Boyraz (2019) and Çakır (2019), no significant difference was found between the groups.

According to the findings related to the effect of educational robotic applications on academic achievement by subject, it was observed that there was a difference between subjects and the largest coefficients were in the subjects of Science (Hedge's g = 1.134) and Algorithm (Hedge's g = 1.121). These results were very large according to Thalheimer and Cook (2002). Yet, when the literature was examined, in the studies conducted by Barker and Ansorge (2007), Kılınç (2014), Bird (2016), Usengül (2019), Şimşek (2019), Çukurbaşı (2016) and Gündoğdu (2020), significant results were obtained in favor of the experimental group. Among the findings of the study, the effect of educational robotic applications on academic achievement based on education level was examined and it was concluded that there was a significant difference in favor of the middle school level (g = 0874, Qbetween = 1.608, p = 0.000). This value seems to indicate a large effect according to Thalheimer and Cook (2002).

Considering the themes and codes constructed in the meta-thematic analysis of the studies on educational robotic applications, among the general features of educational robotic applications were "relating to real life", "learning by doing and experiencing", "provides concrete experiences", "active participation", "increases motivation", "allows for different activities", "developing a different perspective", and "trial-correction possibility". According to Kabátová and Pekárová (2010), educational robotic applications are advantageous in terms of providing students with the opportunity to learn by doing and experiencing and providing a fun working environment. According to Catlin & Blamires (2010), educational robotic applications provide active learning by presenting concrete experiences to students. According to Mitnik (2009), educational robotic applications are applications that increase the motivation level of students and ensure collaborative work. In addition, educational robotic applications are a great opportunity to teach students to produce solutions for real-life problems (Eguchi, 2014). In addition, this conclusion is parallel to the findings of Kılınç (2014), Çukurbaşı (2016), Passenger (2018), Ulloa-Higuera (2019), Pine (2019), Akca (2020) and Gündoğdu (2020). In the meta-thematic analysis, it was seen that educational robotic applications have cognitive, affective and social effects such as "increases success", "easy to learn", "more in-depth learning", "more permanent learning", "self-regulation", "self-evaluation", "pleasurable", "interesting", "enjoyable", "satisfaction", "intriguing", "self-confidence", "self-knowledge", "communication", "interaction", "cooperation", and "working with the group". According to Kabátová and Pekárová (2010), educational robotic applications improve students' characteristics such as collaboration, group work, and taking responsibility. Nourbakhsh et al., (2005) also stated that educational robotic applications improved students' self-confidence and communication skills. Review of the literature revealed that this result was similar to the findings of Kılınç (2014), Çukurbaşı (2016), Hong et al. (2016), Passenger (2018), Hangün (2019), Ulloa-Higuera (2019), Pine (2019), Akca (2020) and Gündoğdu (2020). When the themes constructed for the difficulties experienced during educational robotic applications and the suggestions for this process were examined, the difficulties related to educational robotic applications were "concern", "technical issues", "very time consuming", " difficulty in learning " and "feeling of failure" while the suggestions were "making different designs", "using robots in other subjects and lessons" and "using robots in daily life". This finding was similar to the findings of Kılınç (2014), Çukurbaşı (2016), Passenger (2018) and Gündoğdu (2020).

Suggestions

Considering the findings of the study, the following recommendations have been developed:

- As a result of the quantitative findings obtained from the study, it was seen that educational robotic applications had a positive and strong effect on students' academic achievement. Also, qualitative findings of the study indicated that educational robotic applications made many cognitive, affective, and social contributions to students. In this context, robotic applications should be integrated into educational environments and their use should be increased.
- It was revealed that studies on educational robotic applications were mostly conducted in the field of science. Studies on social areas should be increased in this regard.
- It was revealed that the studies on educational robotic applications are mostly aimed at middle school students. In this context, applications in other education levels should be increased.
- It was stated that students had some technical problems and learning difficulties in the process of educational robotics applications. Necessary measures should be taken against technical problems, and studies should be carried out for students with learning difficulties.

Note: References starting with * were included in the meta-analysis.

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