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The Effect of Metacognitive Strategy-Based Geometry Education on Young Childrens' Metacognitive and Executive Functions Skills

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Abstract

This study aims to investigate the effect of the Metacognitive Strategy-Based Geometry Education Program (McGEP) on children's metacognition and executive function skills and the permanence of this effect. The study was designed in a quasi-experimental design with pretest-posttest control group with a total of 27 children attending to kindergartens affiliated to the Ministry of National Education in Ankara City Center in the 2021-2022 academic year. WM, HTKS, FIST and Train Track Task were used to collect the data. Mann Whitney-U test, Wilcoxon signed-rank test and Friedman test statistics were used to analyze the data. As a result of the study, it was determined that the McGEP had significant effect on children's metacognitive skills of monitoring and control processes and that this effect was permanent. Moreover, it was found that the perseveration and distraction errors exhibited by the children decreased significantly after the implementation of the McGEP. In fact, it was found that there was significant difference in the three sub-tasks of the Train Track task in the sub-domains of Control, Metacognitive Skills, Perseveration and Distraction Errors, and Quality Score in favor of the children in the study group. Accordingly, it was found that the McGEP had significant effect on working memory, cognitive flexibility and inhibitory control skills among children's executive function skills and that this effect was permanent. Therefore, it was concluded that the McGEP significantly affected both metacognitive skills and executive function skills of children.

Keywords: Metacognitive skills, executive function, metacognitive strategy, young children

Introduction

Children need to use processes such as setting goals, making plans, acting flexibly, organizing their information, keeping or changing information in working memory, monitoring and controlling themselves while they are learning. It is important to support the development of metacognition and executive functions, as the ability to monitor and regulate one's self will enable them to become mature and responsible individuals who can control their behaviors (Cragg & Nation, 2007). Being in interaction with different individuals throughout life, adapting to the expectations of educators in the classroom and learning how to adapt to their environment are important aspects of children's lives. Therefore, in order to support children's living spaces, educators and parents should focus on interrelated metacognition and executive function skills (Bryce et al., 2015; Roebers et al., 2012).

Metacognitive Skills in Young Children

The concept of metacognition was first introduced as a result of Flavell's (1976) research on children's memory development. In this study, metacognition was used to describe individuals' knowledge of their own cognitive processes and their ability to control these cognitive processes. Metacognition, is the awareness of one's own cognitive processes and the ability to control these processes (Brown, 1987; Flavell, 1979; Hacker & Dunlosky, 2003; Jager et al., 2005). Many metacognitive models have been developed. However, in this study, Nelson and Narens' (1990) model, which proposes that cognitive processes are split into two interrelated levels (object-level and meta- level), was adopted. The direction of information flow between these two levels represents "monitoring" (when information flows from object-level to meta-level) or "control" (when information flows from meta-level to object-level). Some studies showed that monitoring and control skills emerge in the preschool period reporting that three, four and five-year- olds accurately monitoring the process during a perceptual

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identification task and responded strategically to the questions asked (Coughlin et al., 2015; Lyons & Ghetti, 2013).

Metacognitive Strategies and Math in Young Children

Metacognitive strategies are expressed as a set of methods used to help a person think about thinking (Pressley et al., 1985). The application of metacognitive strategies involves planning one's learning process, monitoring the level of understanding in the process and evaluating one's progress in the learning process (Hattie, 2012). Current research on metacognitive learning strategies shows that these strategies are complex and that metacognition does not include a single technique (Zimmerman, 2002). For this reason, there are many strategies in the literature (Costa, 1984; Blakey & Spence, 1990; Mayer, 1998; Schraw, 1998) to improve individuals' metacognitive skills. The metacognitive strategies adapted to preschool education and used in this study are planning, questioning, modeling, thinking deeply and reflecting thoughts to the other person, thinking aloud and talking about thinking, pair problem solving, and problem solving activities (Blakey & Spence, 1990; Costa, 1984). In research on metacognition, the use of educational strategies that support metacognition and the importance of creating social environments that support metacognition have recently emerged. In addition, metacognition supported education programs increasingly focus on improving individuals' knowledge and perceptions about themselves in learning processes as well as domain specific knowledge (e.g. mathematics and reading skills) (Lin, 2001). It is known that metacognition has significant effects in mathematics education (Biryukov, 2004). Beyond knowing mathematical concepts, it is stated that children learn better and faster when metacognitive strategies are included in the education process (Zelazo, 2015). The use of metacognitive strategies in the educational environment contributes to the realization of flexible, creative and strategic learning (Chatzipanteli et al., 2014). This study is promising in terms of sup- porting metacognitive skills in the preschool period.

Executive Function in Young Children

Executive functions are a system that is needed in all kinds of situations encountered in daily life including the cognitive processes necessary for planning and directing activities such as initiating and continuing a task, as well as the mental processes necessary for controlling one's own thoughts and behaviors to achieve a goal (Cooper-Kahn & Foster, 2013). Therefore, executive functions are explained as an umbrella term that includes cognitive processes that manage purposeful actions and flexible, adaptive responses to changes in the environment (Hughes & Ensor, 2008). Miyake et al. (2000), who set an example for many recent studies on executive functions in children, explained executive functions as a single structure with partially separable components including working memory, inhibitory control and cognitive flexibility. In this study, the researchers discussed three basic executive function component processes. These are inhibitory control (inhibition of strong reactions), cognitive flexibility (switching between mental clusters), and updating and monitoring representations in working memory. Thus, based on the different views on executive functions, many researchers have proposed that the structure of executive functions can be divided into three separate but interrelated components. These are working memory, inhibitory control, and cognitive flexibility (Diamond, 2013; Huizinga et al., 2006; Miyake et al., 2000; Lehto et al., 2003). Working memory involves retaining, processing, and recalling information (Allan et al., 2015). Inhibitory control is the ability to ignore irrelevant stimuli or information to complement a dominant response or goal-directed behavior (Anderson et al., 2010). Cognitive flexibility is the ability to switch between different tasks or different sets of rules (Diamond, 2013).

Relation Between Metacognition and Executive Function Skills

Although Metacognition and executive functions continue to mature, the most radical changes observed in executive functions occur between the ages of four and six (Carlson, 2005; Huizinga et al., 2006). Similarly, rapid changes in metacognition are observed between the ages of three and seven (Bryce et al., 2015; Roebers et al., 2012). Roebers (2017) recently proposed a unifying framework for metacognition and executive functions and suggested that these are overlapping constructs. It is accepted in the literature that there is a close relation- ship between executive functions and metacognition. Several neuroimaging studies suggest that brain activation is observed specifically in the prefrontal cortex when performing typical executive function or certain metacognitive tasks (Kao et al., 2005). Several studies in the literature prove a direct relationship between executive function and metacognition, and these studies mainly focus on working memory. Better working memory skills are associated with more productive metacognitive functioning in both adults and children (Dunlosky & Thiede, 2004; DeMarie et al., 2004). The emergence of early metacognitive skills is attributed to children's awareness of their own executive functions and thus more control over their own learning (Marulis et al., 2020). By the age of about five, children are expected to have typical executive function skills, that is, to have developed their ability to retain information. These skills include the ability to follow multi-step instructions (working memory) during classroom activities. Meanwhile, children with typical executive functioning skills are able to focus on relevant information (i.e., sustained attention, working memory, and inhibition), especially during math problem-solving tasks (Fitzpatrick et al., 2014). Research shows that executive functioning is strongly and positively related to basic number skills and later mathematics achievement (Gashaj et al., 2019; Geary et al., 2008). Although both metacognition and executive functions have been evalu- ated together with academic achievement in studies, metacognition and executive functions have mostly been discussed separately in the literature (Blair & Diamond, 2008; Roebers, 2017). Generally, research on executive functions in preschool period prioritizes clarifying the relationships between the components of executive functions, while metacognition research in this period tends to focus on improving activities and learning. For this reason, it can be said that experimental evidence on the relationships between metacognition and executive functions is insufficient (Marulis et al., 2020). The studies reporting a relationship between metacognition and executive functions focused on establishing a theoretical link between these two constructs and did not include empirical measurements of these constructs (Chevalier et al., 2015; Kovac-Cerovic, 1996; Watson & Westby, 2003; Whitebread et al., 2009). As a result, experimental studies are needed to explain the relationship between executive functions and metacognition. There are limited studies examining both metacognition and executive functions (Bryce et al., 2015; Chevalier & Blaye, 2016; Geurten et al., 2016; Marulis et al., 2016; Murray et al., 2016; Roebers et al., 2012; Whitebread, 1999). However, there are few studies in which metacognition and executive function skills associated with mathematical skills are explained by experimental methods (Roebers, 2017). Therefore, it is considered important to integrate metacognition and executive functions in an experimental research context. This study aims to obtain empirical results to test the effect of a learning process using metacognitive strategies on both metacognitive skills and executive functioning skills of children in preschool period. This research will provide researchers and educators with a different perspective on the use of metacognitive strategies in educational programs designed to support the development of executive function skills. On the other hand, considering that executive functions have strong relationships with mathematics and geometry skills (Schmitt, et al., 2018), it is thought that the executive functions of preschool children will improve thanks to Metacognitive Strategy-Based Geometry Education Program (McGEP). This research sought to answer the following questions:

- Does McGEP affect children's metacognitive skills? Is this effect permanent?
- Does McGEP affect children's executive function skills? Is this effect permanent?

Method

Research Design

A pretest posttest control group quasi-experimental design was used in the study. Accordingly, two of the existing groups are matched according to certain variables. In this study, the groups were matched in terms of metacognition and executive function skills. Groups matched in this design are randomly assigned as the experimental and control groups (Büyüköztürk et al., 2014). At the beginning of the treatment, "Working Memory Scale (WM)", "Flexible Item Selection Task (FIST)", "Head-Toes-Knees-Shoulders Touching Instructions (HTKS)" and "Train Track Task" were administered to determine whether the groups matching or not and it was revealed that there was no significant difference ($p>.05$) between the pre- test scores of the study groups.

Participants

The study was conducted with 27 (14 females) children attending to a preschool affiliated to Ministry of National Education in Ankara Türkiye. Children are in two separate classes with five age groups. A study group in which the McGEP was employed (n=15) and a control group (n=12) were designated randomly among these subjects. The study group was determined according to some criteria. Firstly, it was important to choose schools with responsive principals and teachers. Another criterion is the age of the children. Researchers state that although preschool children are cognitively developed, they can show metacognitive control towards the end of the earliest preschool period, and that metacognitive skills develop depending on age (Flavell, 1979). Based on this view, it was studied with children in the older age group (five years old) in the pre-school period.

Data Collection Tools

In this study, "WM", "FIST", "HTKS" and "Train Track Task" were used to collect data on children's executive function and metacognitive skills. Information on measurement tools is presented below.

Working Memory Scale (WM)

The working memory scale was developed by Ergül et al. (2018) to assess the working memory performance of children from preschool to fourth grade. This scale consists of four subdomains and nine sub-scales that assess verbal/visual short-term memory, verbal/visual working memory related to verbal memory and visual memory sub-domains. This scale consists of four sub-domains and nine sub-scales. WM scale is applied to children individually. In each subscale, children are given an increasing number of sequences and asked to repeat them in the same way. In tasks for working memory, children are presented with two-task operations that require simultaneous processing. Each item consists of two trials. When the child is successful in one of the two attempts, he or she can move on to the next item. In case of failure in both trials, the relevant subscale is terminated. In the scale, each correct answer is scored as 1 and incorrect answer as 0. By summing the subscale scores, subscale, sub-domain and overall total score are obtained. For the validity of the scale; Content validity, criterion validity and construct validity studies were carried out. Content validity was determined in line with the opinions obtained from experts in different fields. Principal component analysis, cluster analysis and CFA were performed to deter- mine the construct validity. The fit statistics of the scale were found to be $x2=49.97$ (N=860, sd=25, $p<.01$), $x2/sd=1.99$, RMSEA=.08 at the preschool level. The Cronbach Alpha coefficient calculated for the internal consistency reliability based on the test split method was found to be between .68 and .99 (Ergül et al., 2018).

Flexible Item Selection Task (FIST)

FIST was developed by Jacques and Zelazo (2001) to measure children's cognitive flexibility skills. This task consists of "abstraction" and "cognitive flexibility" sub-dimensions. The validity and reliability study of the test with Turkish children was conducted by Şahin (2015). FIST includes 18 trials. In this test, in each trial, children are shown three objects that appear on a different page. These objects consist of three-dimensional combination. These; color, shape and size. Each dimension is represented by three objects, respectively. FIST consists of a demonstration trial, 2 application trials, and 15 test trials. Selection 1 and selection 2 are included in each trial. In selection 1, the children are asked to choose two objects that are similar in one aspect. In Selection 2, he is asked to choose two objects that are similar to each other in another aspect. Thus, abstraction skills are measured in selection 1 and cognitive flexibility skills are measured in selection 2. In scoring the test, children who get a match correct on their first try get a point. . If they make the second choice correctly, they also get one point for the second match. In total, the highest score is 15 for abstraction skills and 15 for cognitive flexibility.

The Cronbach Alpha value of the test was calculated as .81 for abstraction skills and .86 for cognitive flexibility. On the other hand, test-retest was performed to determine the consistency of the sub-dimensions of the test, and there was a statistically significant correlation between the abstraction skills sub-dimension scores (r=.886 p<0.01) and cognitive flexibility sub-dimension scores (r=.898 p<0.01). (Sahin, 2015).

Head-Toes-Knees-Shoulders (HTKS)

HTKS was developed by Ponitz et al. (2008) to evaluate the behavior regulation skills of 3-7-year-old children. The Turkish adaptation study was carried out by Sezgin (2016). HTKS measures children's attention, working memory, inhibitory control skills, integration of executive function skills. In order to be successful in this task, children need to pay attention to the commands of the researcher, use their working memory to remember new rules, and be able to respond unnaturally by preventing their natural response to commands in order to give the right response. The main component of the HTKS is inhibitory control. It is seen that HTKS is used to measure inhibitory control in studies (Clements et al., 2016; Gandolfi et al., 2021; Heibel-Witte, 2016; Malone et al., 2019). In this research, HTKS was used to measure the inhibitory control skill. The assessment tool consists of three separate tasks, each consisting of 10 tasks. In the first level, children are asked to touch their head when they are given the "touch foot" task, and to touch their foot when they are given the "touch head" task. If the children are successful in the head/foot tasks, level second is passed. In the second level, children are asked to touch their knees when they are given the "touch your shoulder" task, and to touch their shoulders when they are given the "touch your knees" task. If children are successful in the knee/shoulder task, level three is passed. At the third level, children are asked to forget the first and second level tasks and apply the new tasks. A child who gets four or more points from each level can move on to other levels. Children get two points if they get the task right, one point if they make any move towards the wrong answer, and zero points if they fail the task. HTKS score range is 0-60 points. As a result of the CFA analysis of the HTKS, it is seen that the regression values vary between 0.23 and 0.83 and the t values vary between 8.38 and 26.56. The Cronbach Alpha values of the HTKS were 0.933 for the first level; 0.957 for the second level; 0.94 for the third level and 0.96 for the whole scale. These results show that the reliability of HTKS is high.

The Train Track Task

Train Track Task was developed by Bryce and Whitebread (2012) as a result of adapting the circuit railway task and coding them according to metacognitive skills. In this task, verbal and non-verbal metacognitive skills that children show while completing a problem-solving task are coded by means of controlled observation. In this task the children are asked to build a train track from wooden blocks (train tracks) according to a predefined shape. The children were asked to build three train tracks shaped like an "oval" (O), "goggle" (B) shape and "P" shape. Below are the shapes presented to the children (Figure 1):

Children are videotaped during the task. Afterwards, examples of positive (Monitoring and Control) and negative (Perseveration and Distraction) metacognitive behaviors shown by children are examined according to the Metacognitive Skills Checklist and Perseveration and Distraction Checklists developed by Bryce and Whitebread (2012). Metacognitive

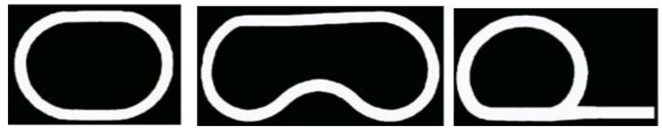


Fig..1: The train track plan

Skills Checklist consists of two sub-dimensions, Monitoring and Control, and Perseveration and Distraction Checklist consists of two sub-dimensions, Perseveration and Distraction errors. The similarity of the train track made by the children to the original shape is scored as Quality Score, and the highest score they can get is six points. The validity and reliability study of the Train Track Task with Turkish children was carried out by Pekince and Avcı (2021). In the study, which was conducted by examining the video recordings of 57 children aged between 4-5 years, the reliability of compliance between the raters was realized with the Fleiss Kappa statistic, and the reliability was high in all sub-dimensions. In the scoring of the task, the metacognitive behaviors of the children during the task were coded and the duration of the task was calculated. Before the analyzes, in order to find the average number of behaviors per minute regarding the sub-domains of the task, the frequency of observed behaviors for each sub-domain was divided by the total time (minutes) and mean values were obtained. Statistical analyzes were carried out on mean values. The mean rank values presented in the graphs represent the rate of increase or decrease in the frequency of behavior per minute of the children.

Procedure

Implementation the Pre-tests

Necessary permissions were obtained from Ankara Provincial Directorate of National Education and Gazi University Ethics Commission for the implementation of McGEP. Then, WM, HTKS, FIST and Train Track Task were applied to 15 children in the study group and 12 children in the control group between September 20 and October 15, 2021. These tests were administered invidually by the researcher.

Study Group Implementation

McGEP was developed by Yıldız Altan (2022) and was shaped to improve children's metacognitive skills. The McGEP was based on the metacognition models of Flavell (1987) and Nelson and Narens (1990). The activities and cognitive tasks in McGEP were designed to develop children's planning, monitoring and control, and evaluation skills. Solving problems for children who encounter a cognitive task requires them to use information flow mechanisms effectively. Therefore, metacognitive questions were included in the content of the program, as children's self-talk helps them gain the ability to ask questions and the flow of information in monitoring and control processes. In addition, it was emphasized that children should be able to express their cognitive processes, interact with each other and cooperate in activities. Different assessment methods were used for children to comment and evaluate both their own cognitive processes and the cognitive processes of their peers. These are evaluation methods include video recording how an activity and discussing it by reflecting this video, photographing the process and allowing children to make evaluations by reflecting these photographs, creating graphics and drawing pictures. At the same time, care was taken to support these events with all types of activities. In fact, the activities were not prepared only mathematical activity, but were integrated with other types of activities such as music, drama, movement, and games. Rather than introducing geometric shapes and teaching concept in the content of McGEP, childrens metacognitive skills were tried to be supported by using geometry activities. Geometry activities were used as a tool to create context in the process of supporting children's metacognitive thinking. The learning outcomes and indicators supported within the scope of McGEP were created by the researcher. Metacognitive strategies were taken as a basis while creating the outcomes. The strategies addressed within the scope of McGEP are thinking aloud and talking about thinking, explaining what they know and what they don't know, thinking deeply and reflecting their thoughts, modelling, planning, creating questions, summarizing their thinking processes, self-evaluation, problem solving. For example, the outcomes and indicators developed for the strategy of thinking aloud and talking about thinking are as follows. "K3: Explains his/her thoughts about the completion of the activity process. G1: Explains the similarities and differences between the processes to be completed. G2: Tells whether completing the activity process is appropriate for his/her competencies. G3: Explains the similarities and differences between his/her own and others' competencies in completing the process." Care was taken to use materials that would attract children's attention and help them concretize their thinking processes. For this reason, rich material content was presented in the learning process. These materials include wooden cube blocks, tangrams, strategy games, nesting cubes, bamboo sticks, dominoes, educational shapes and block building games. In addition to these ready-made materials, materials prepared by the researcher were also used in the process. Some of these materials are strategic triangle puzzle, cube puppets, shape and number cards, start-stop plates. The purpose of presenting a rich variety of materials to children is to both concretize their cognitive processes and to enable them to think aloud to express these processes. Before the actual implementation of the McGEP, pilot study was conducted to evaluate the suitability and applicability of the activities for five-year-old children. The pilot study was conducted at Gazi University Practice Kindergarten. The pilot study was carried out in the fall semester of the 2020-2021 academic year. The actual implementation of McGEP was applied to the study group in 20 sessions by the researcher between October 19 and December 21, 2021. The implementations were carried out two days a week on Tuesday and Thursday. During the implementation process, the researcher organized the educational environmentin advance and prepared the materials to be used in advance. During the sessions, the researcher presented the activities to the children and avoided intervening in the process as much as possible. It was emphasized that children worked in small groups during the activities. In designing and implementing the activities, the contexts that develop young children's meta- cognitive skills were taken into consideration. Each activity in the McGEP had a level of difficulty that children could control and provided children with a sense of control and opportunities to express their thoughts. Therefore, each child was encouraged to speak his/her opinion aloud during the process. The implementation of each session lasted between 60-90 minutes on average.

Control Group Implementation

The researcher informally observed the mathematics activities of the control group in order to communicate with the children and to determine how the mathematics activities were carried out. It was observed that the teacher focused on teaching the mathematics skills and geometry concepts specified in the 2013 Preschool Education Program of the Ministry of National Education.

Implementation of Post-Test and Follow-up Tests

After the implementation of the McGEP, the study group and the control group were administered the WM, FIST, HTKS and Train Track Task as post-tests between December 27 and January 14, 2021. After the post-tests, follow-up tests were administered approximately four weeks after the post-tests in order to test the retention of the McGEP. The measurement tools administered in the post-tests were administered only to the children in the study group during the follow-up tests between February 14 and March 5, 2022.

Data Analysis

Nonparametric methods were used in the statistical analyses. For parametric methods, the normality of the data distribution and the number of data in the groups are expected to be large enough (N>30) (Tabachnick & Fidell, 2013). Since the number of data in the study and control groups in this study was (N<20) nonparametric methods were used. Mann Whitney-U analysis was used to compare the scores of the study and control groups and Wilcoxon signed-rank test was used to compare the pre-test and post-test scores in the control group. In addition, Friedman test was used to compare the pre-test, post-test and follow-up test scores in the study group. For the measurements that showed a significant difference according to the Friedman test, Wilcoxon signed-rank test was used to compare which measurements the differences were between. For the statistical analyzes, p<.05 significance level was tested.

Findings

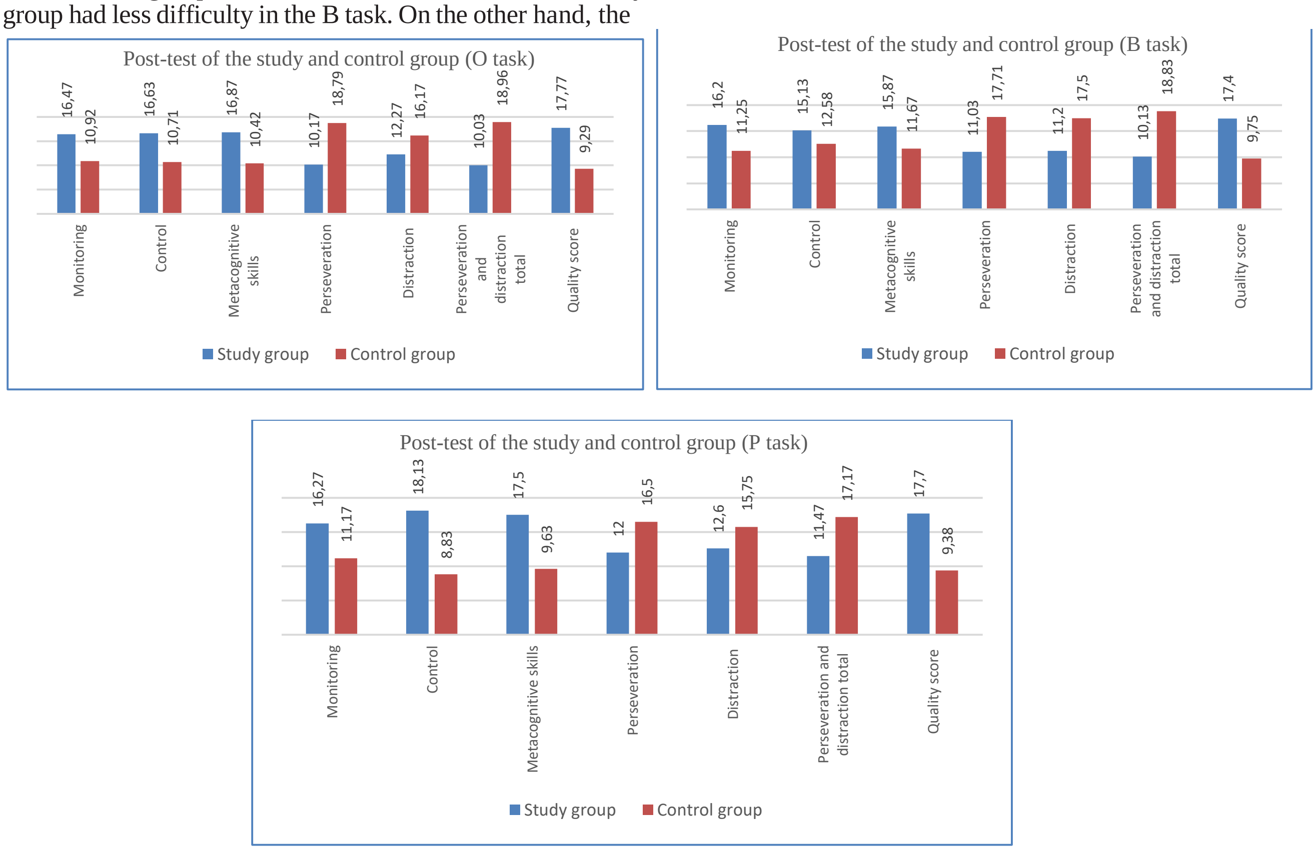
The findings obtained in this study, which was conducted to examine the effect of McGEP on children's metacognition and executive function skills, are explained under the research questions.

Does the McGEP affect children's metacognitive skills? Is this effect permanent? The effect of the McGEP on children's metacognitive skills was examined by comparing the post-test scores of the children in the study group with the post-test scores of the children in the control group.

The Mann Whitney U analysis method was used to test whether there was a difference between the post-test rates obtained from the study group and the control group in the sub-domains of the Train Track O, B and P task

When Figure 2 is examined, a statistically significant difference was obtained between the posttest of the children in the study and control groups in the subdomains of the Train Track O task; monitoring and control total (Z=-2.098, p<.05), perseveration (Z=-3.024, p<.05), perseveration and distraction total (Z=-3.129, p<.05) and quality score (Z=-2.82, p<.05). A statistically significant difference was found between the posttest of perseveration (Z=-2.229, p<.05), distraction (Z=-2.659, p<.05), perseveration and distraction total (Z=- 2.868, p<.05) and quality score (Z=-2.556, p<.05) from the B task sub-domains. A statistically significant difference was obtained between the post-test of control (Z=-3.026, p<.05), monitoring and control total (Z=-2.652, p<.05), perseveration and distraction total (Z=-2.036, p<.05) and quality score (Z=-2.776, p<.05) from the P task sub-domains. The post-test mean ranks of the children in the study group were higher than those of the children in the control group in the O task sub-domains of monitoring and control total ratios and quality score. However, the posttest mean ranks of the children in the control group were higher than those in the study group for the O task perseveration and perseveration and distraction ratios. This shows that the children in the control group made perseveration and distraction more frequently per minute in the post-tests compared to the children in the study group. In addition, the posttest mean rank order of the B task quality score of the children in the study group was higher than that of the children in the control group. This shows that the children in the study group had less difficulty in the B task. On the other hand, the post-test mean ranks of the children in the control group were higher than those in the study group for the ratios of perseveration, distraction, and perseveration and distraction total. This shows that the children in the control group made perseveration and distraction error more frequently in one minute in the post-tests compared to the children in the study group. The posttest mean ranks of the children in the study group were higher than those in the control group in the sub-domains of control, monitoring and control total and quality score of the P task. However, the post-test mean ranks of the children in the control group were higher than those in the study group of perseveration and distraction total. This shows that children in the control group made perseveration and distraction error more frequently in the post-tests. This shows that the frequency of metacognitive behaviors that the children in the study group showed in one minute in the post-tests was significantly higher compared to the children in the control group. Therefore, it can be said that the McGEP positively affected the frequency of children's metacognitive behaviors. At the same time, it was determined that the perseveration and distraction errors of the children in the study group were significantly lower in one minute compared to the control group. This situation reveals that the McGEP has a positive effect on increasing children's metacognitive behaviors while reducing their perseveration and distraction errors (Figure 2).

In addition, the quality score is score the children received for how similar the shape they made was to the plan shown. When the post-tests of the study and control groups are compared, it is seen that the study group made higher quality

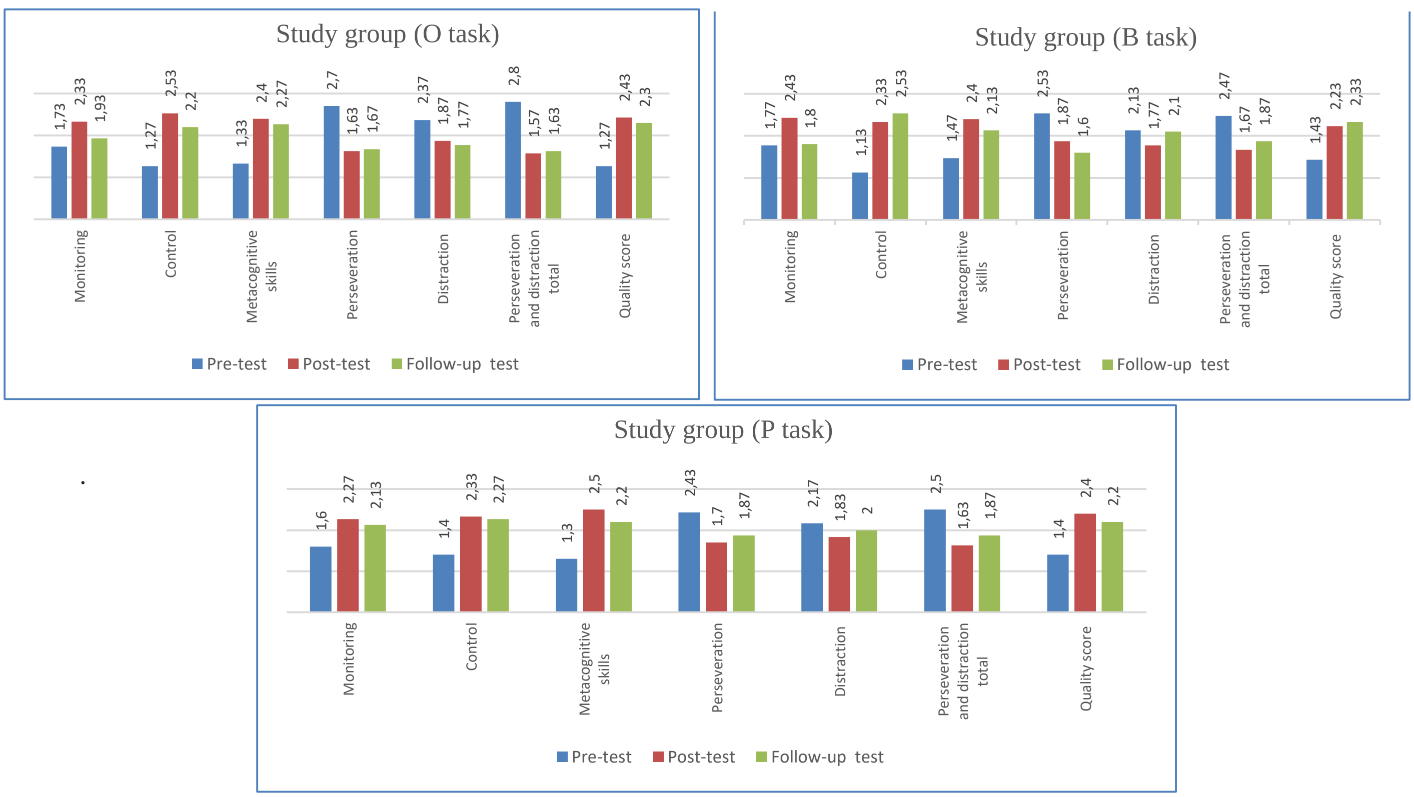


*p<.05

Fig. 2: Mann Whitney U Test results for the difference between the post-tests of the O, B and P task in the study and control groups

shapes than the control group in the O, B and P tasks. This shows that children in the control group had more difficulty than the study group in the post-tests.

The permanence of the effect of the McGEP on children's metacognitive skills was examined by comparing the pre- test, post-test and follow-up test scores of the children in the study group. Whether there was a difference between the pre-test, post-test and follow-up tests of the study group was compared with the Friedman analysis method. Figure 3 shows the statistical comparison results regarding the frequency of metacognitive behaviors that the children in the study group showed in one minute during the pre-test, post-test and follow-up tests. In the study group, a statistically significant difference was obtained in the control ($\chi2$ =12.933, p<.05), monitoring and control total ($\chi2$ =10.133, p<.05), perseveration ($\chi2$ =15.762, p<.05), distraction ($\chi2$ =8.857, p<.05), perseveration and distraction total ($\chi2$ =20.14, p<.05) and quality score ($\chi2$ =14.98, p<.05) from the O task sub-domains. The source of the difference was compared Wilcoxon's signed-rank method and the difference between the measurements was indicated in the column graph. For all measurements that showed a difference, a difference was obtained between the pre-test and post-test and between the pre-test and follow-up tests, and there was no difference between the post-test and follow-up tests. This shows that the increase in the metacognitive skills of the children in the study group was permanent. On the other hand, in the study group, the pre-test mean ranks of the O task sub-domains of perseveration, distraction, perseveration and distraction total were higher than the post-test and follow-up. This shows that the perseveration and distraction errors of the children in the study group in the O task decreased significantly during the posttest and follow-up tests, and this decline continued in the follow-up tests. A statistically significant difference was obtained in the control ($\chi2$ =17.2, p<.05), monitoring and control total ($\chi2$ =6.933, p<.05), perseveration ($\chi2$ =8.667, p<.05), perseveration and distraction total ($\chi2$ =6.5, p<.05) and quality score ($\chi2$ =9.955, p<.05) from the B task sub- domains. In the other sub-domains of the B task, except for perseveration, there was a difference between the pre-test and post-test and between the pre-test and follow-up tests, but the difference between the post-test and follow-up tests was not significant in the perseveration measurement. In addition, in the study group, the post-test and follow-up test for the control, monitoring and control total and quality scores were higher than the pretest. However, in the study group, the pre-test for perseveration and distraction total were higher than the post-test and follow-up. This shows that the perseveration and distraction total error in one minute in the B task decreased significantly in the posttest compared to the pretest, and this decrease was permanent. Similarly, in the study group, the pre-test of perseveration rates in the B task were higher than the post-test. These findings show that the metacognitive skills of the children to whom the McGEP was applied increased significantly in the post-test of the B task and the perseveration and distraction error during the task decreased significantly. A statistically significant difference was obtained in control ($\chi2$ =8.133, p<.05), monitoring and control total ($\chi2$ =11.898, p<.05), perseveration ($\chi2$ =6.821, p<.05), perseveration and distraction total ($\chi2$ =8.829, p<.05) and quality score ($\chi2$ =12.293, p<.05) from the P task sub- domains.



*p<.05 ** Wilcoxon Test Comparison

Fig. 3: Mann Whitney U Test results for the difference between the pretest, posttest and follow-up tests of the O, B and P task in the study group

In the other sub-domains of the P task, except for perseveration, there was a difference between the pre-test and post-test and between the pre-test and follow-up tests, but the difference between the post-test and follow-up tests was not significant. This finding shows that the increase in the metacognitive skills of the children to whom McGEP was applied in the post-tests continued in the follow-up tests, thus showing the permanence of the education program applied. Therefore, the significant frequency of metacognitive behaviors exhibited by the children in the posttest and follow-up tests compared to the pretest reveals the positive effect and permanence of the McGEP. Finally, when the quality score was evaluated, it was observed that children made significantly higher quality shapes in the posttest and follow-up tests compared to the pretest, and this quality continued in the follow-up tests. These findings prove that the children to whom the McGEP was applied also made significant improvements in the Train Track Task in the post-tests and follow-up tests compared to the pretests. Both the children's quality scores and their monitoring and control skills, which are metacognitive skills, improved. While these skills improved, it was also found that the perseveration and distraction errors

Table 1: Mann Whitney U Test Results Regarding the Difference Between the Working Memory Post-tests of the Study and Control Groups

	Sub-domain	*Sub-scale*	*Group*	*Average*	*Rank Mean*	*Row Total*	*Z*	*p*
VERBAL MEMORY	Verbal Short-Term Memory	Number Remembering	Study	1.207	16.57	248.5	-1.929	0.054
			Control	1.155	10.79	129.5		
		Word Remembering	Study	0.799	17.37	260.5	-2.682	0.007*
			Control	0.965	9.79	117.5		
		Meaningless Word Remembering	Study	0.961	15.97	239.5	-1.526	
			Control	0.669	11.54	138.5		0.127
		Verbal Short-Term Memory Total	Study	2.503	17.63	264.5	-2.689	
			Control	1.679	9.46	113.5		0.007*
	Verbal Working Memory	Back to Number Remembering	Study	1.447	15.80	237.0	-1.400	
			Control	1.379	11.75	141.0		0.162
		First Word Remembering	Study	0.915	15.07	226.0	-0.825	
			Control	0.835	12.67	152.0		0.409
		Verbal Working Memory Total	Study	1.897	15.93	239.0	-1.438	
			Control	1.658	11.58	139.0		0.150
		Verbal Memory Total	Study	67.069	17,13	257.0	-2.300	
			Control	46.044	10,08	121.0		0.021*
VISUAL MEMORY	Visual Short-Term Memory	Pattern Matrix	Study	1.069	14.40	216.0	-0.313	
			Control	0.835	13.50	162.0		0.754
		Block Remembering	Study	0.941	16.97	254.5	-2.334	
			Control	0.900	10.29	123.5		0.02*
		Visual Short-Term Memory Total	Study	1.612	16.03	240.5	-1.528	
			Control	1.485	11.46	137.5		0.127
	Visual Working Memory	Choosing Different	Study	1.298	16.87	253.0	-2.196	
			Control	0.793	10.42	125.0		0.028*
		Spatial Remembering	Study	0.676	15.87	238.0	-1.507	
			Control	0.905	11.67	140.0		0.132
		Visual Working Memory Total	Study	1.682	17.20	258.0	-2.422	
			Control	1.505	10.00	120.0		0.015*
		Visual Memory Total	Study	75.339	17.30	259.5	-2.421	
			Control	86.905	9.88	118.5		0.015*
		Working Memory Total (Verbal Memory + Visual Memory)	Study	71.128	17.20	258.0	-2.346	
			Control	60.504	10.00	120.0		0.019*

exhibited by the children during the task decreased significantly (Figure 3). *Does the McGEP affect children's executive function skills? Is this effect permanent?* The effect of the McGEP on children's executive function skills was examined by comparing the post-test scores of the children in the study group and the control group. The Mann Whitney U analysis method was used to test whether there was a difference between the posttest obtained from the study and control groups in working memory measurements. When Table 1 is examined, a statistically significant difference was obtained between the post-test scores of the study and control groups in word recall (Z=-2.682, p<.05), verbal short-term memory sub-domain (Z=-2.689, p<.05), verbal memory total (Z=-2.3, p<.05), block recall (Z=-2.334, p<.05), choosing different (Z=-2.196, p<.05), visual working memory sub-domain (Z=-2.422, p<.05), visual memory total (Z=-2.421, p<.05) and working memory total (Z=-2.346, p<.05). It was observed that the mean rank of the study group was higher than the control group for all significant working memory measures. This can be said that the children in the study group showed more improvement in the visual memory sub-dimension compared to the control group at the end of the McGEP interventions. Compared to the verbal memory sub-dimension, there are more sub-domains in which significant difference is observed in the visual memory sub-dimension. Therefore, these findings proved that the effect of the McGEP on visual memory was significant, he permanence of the effect of the McGEP on children's working memory was examined by comparing the pre-test, post-test and follow-up test scores of the children in the study group. The difference between these tests was compared using Friedman analysis method. When Table 2 is examined, no significant difference was found between the pre-test, post-test and follow-up tests in the pattern matrix ($\chi2$ =2.45, p>.05), visual short-term memory sub-domain ($\chi2$=4.68, p>.05) and spatial remembering sub-scale ($\chi2$=5.568, p>.05). A significant difference was found between the pre-test, post-test and follow-up tests for all measures except for these working memory measures, for which no significant difference was found (p<.05). For the source of the difference, the significant variables were compared with Wilcoxon signed-rank test and shown in Table 4. significant difference were found between pre-test, post-test and follow-up tests for word remember, meaningless word remembering, verbal short-term memory sub-domain, verbal working memory sub-domain, verbal memory total and working memory total (p<.05). In these measurements, which were significant in all three tests, the follow-up tests was higher than the pretest and posttest, and the posttest was higher than the pretest.

Significant difference were found between pre-test, post-test and follow-up tests for back to number remembering, block remembering, choosing different, visual working memory total, visual memory total (p<.05) and the post-test and follow-up test for these measurements are higher than the pre-test, but there is no difference between the post-test and follow-up tests (p>.05). For the number remembering and first word remembering measures, the difference between the pre-test and post-test was significant (p<.05) and for these measures, follow-up test was higher than the pre-test and post-test, but there was no significant difference between the post-test and pre-test scores (p>.05). Finally, for the choosing different, only the difference between the pre-test and the follow-up test was significant (p<.05) and the follow-up test was higher than the pre-test. When these findings are examined, it is seen that the children to whom the McGEP was applied showed significant improvement in the post-test and follow-up tests compared

Table 2: Wilcoxon Test Results Regarding the Difference Between the Working Memory Measurement of the Study Group

	Sub-domain	*Sub-sclae*	*1-2* *p*	*1-3* *p*	*2-3* *p*
VERBAL MEMORY	Verbal Short-Term Memory	Number Remembering	0.285	0.021*	0.014*
		Word Remembering	0.001*	0.001*	0.023*
		Meaningless Word Remembering	0.011*	0.001*	0.002*
		Verbal Short-Term Memory Total	0.001*	0.001*	0.001*
	Verbal Working Memory	Back to Number Remembering	0.01*	0.017*	0.603
		First Word Remembering	0.086	0.003*	0.026*
		Verbal Working Memory Total	0.004*	0.002*	0.035*
		Verbal Memory Total	0.001*	0.001*	0.001*
VISUAL MEMORY	Visual Short-Term Memory	Block Remembering	0.041*	0.005*	0.796
	Visual Working Memory	Choosing Different	0.092	0.028*	0.458
		Visual Working Memory Total	0.047*	0.015*	1.000
		Visual Memory Total	0.004*	0.002*	0.254
		Working Memory Total (Verbal Memory + Visual Memory)	0.001*	0.001*	0.002*

1: Pre-test, 2: Post-test, 3: Follow-up test, *p<.05 ** Wilcoxon Test Comparison to the pre-test in both verbal memory and visual memory. While the control group showed a significant improvement in the verbal memory dimension in the post-tests, the study group showed progress in both sub-dimensions. In addition, the fact that the significant difference between the follow-up tests and the pre-test and post-tests was observed in many sub-dimensions shows that the MCGEP implementations is permanent. On the other hand, it is also normal that there is no significant difference between post-tests and follow-up tests in other sub-scales. Because the children were not exposed to any intervention during the four-week period between the post-tests and the follow-up tests.

The effect of the McGEP on children's abstraction and cognitive flexibility skills was examined by comparing the post-test of the study and control groups. Table 3 shows the Mann Whitney U analysis results regarding whether there is a significant difference between the FIST post-test (Table 3).

According to Table 3, there is no statistically significant difference between the abstraction ($Z=-1.964$, $p>.05$) and cognitive flexibility post-test ($Z=-1.309$, $p>.05$) in the study and control groups. In other words, it is seen that the cognitive flexibility skill is similar in both groups. The permanence of the effect of the McGEP on children's cognitive flexibility skills was examined by comparing the pre-test, post-test and follow-up test of the children in the study group. Table 4 presents the results of the Friedman analysis regarding whether there was difference between the pre-test, post-test and follow-up tests of the study group (Table 4).

There was significant difference between the cognitive flexibility skills pretest, posttest and follow-up tests ($\chi2=6.745$, $p<.05$). The source of the difference is shown in the difference column, and only the difference between the cognitive flexibility pre-test and follow-up tests was significant and the follow-up test was higher than the pre- test. There was no significant difference between abstraction skill the pretest, posttest and follow-up tests ($\chi2 =0.364$, $p>.05$). Regarding the abstraction skill, it was determined that the pre-test and post-test of the study and control groups were similar and there was no significant increase in this sub-dimension. However, in the cognitive flexibility sub-dimension, control group showed a higher improvement compared to the study group. Therefore, while there was a difference between the pre-test and post-test in the control group, significant difference was found between the pre-test and follow-up test in the study group.

The effect of the McGEP on children's inhibitory control skills was examined by comparing the post-test of the study and control groups. The Mann Whitney U test was used to whether there was difference between the post-test of the study and control groups and the results are presented in Table 5. There was statistically significant difference between level1 ($Z=-3.59$, $p<.05$), level2 ($Z=-3.144$, $p<.05$), level3 ($Z=-3.538$, $p<.05$) and HTKS total ($Z=-3.615$, $p<.05$) the post-test in the study and control groups. It was observed that the mean ranks of study group were higher for all HTKS measurements. This shows that the inhibitory control skills of the children in the study group increased significantly compared to the control group. Therefore, it can be said that the significant difference found is due to the McGEP implemented to the study group. The permanence of the effect of the McGEP on inhibitory control skills was examined by comparing the pre-test, post-test and follow-up test of study group. The Friedman test was used to compare whether there was difference between these tests and the results are presented in Table 6.

Table 3: Mann Whitney U Test Results Regarding the Difference Between Abstraction and Cognitive Flexibility Skills Post-test of the Study and Control Groups

	Sub-domain	*Group*	*Rank Mean*	*Row Total*	*Average*	*Z*	*p*
FIST	Abstraction Skills	Study	15.43	231.5	14.67	-1.302	0.193
		Control	12.21	146.5	14.17		
	Cognitive Flexibility	Study	15.77	236.5	12.87	-1.309	0.191
		Control	11.79	141.5	11.08		

Table 4: Friedman Test Results Regarding the Difference Between Cognitive Flexibility Skills Pre-Test, Post-Test and Follow-up Tests of Study Groups

	Sub-domain	*Measurement*	*Rank Mean*	*Average*	*ss*	*χ2*	*p*	*Difference*
FIST	Abstraction Skills	Pre-test	1.93	14.60	0.74	0.364	0.834	
		Post-test	2.00	14.67	0.82			
		Follow-up test	2.07	14.80	0.41			
	Cognitive Flexibility	Pre-test	1.60	12.07	2.19	6.745	0.034*	1-3**
		Post-test	1.93	12.87	2.13			
		Follow-up test	2.47	13.67	1.63			

There was significant difference between pretest, posttest and follow-up tests for level1 ($\chi2$ =23.343, $p<.05$), level2 ($\chi2$ =19, $p<.05$), level3 ($\chi2$ =22.483, $p<.05$) and HTKS total ($\chi2$ =23.351, $p<.05$). The source of the difference is shown in the difference column. The difference between the pre-test, post-test and follow-up tests for level1, level2 and level3 measurements was significant and the post-test and follow-up test for all these measurements were higher than the pre-test. However, there was no significant difference between post-test and follow-up tests for level1, level2 and level3 ($p>.05$). However, there is significant difference between all groups for the HTKS total. These findings prove that the inhibitory control skills of the children to whom the MCGEP was implemented increased significantly after the education program. On the other hand, the fact that there was no significant difference between the post-tests and the follow-up tests is a normal. Because the children were not exposed to any intervention during the four-week period between the post-tests and the follow-up tests. As a result, it can be said that the McGEP had statistically significant effect on inhibitory control skills and the McGEP was permanent.

Discussion and Conclusion

The purpose of this study is to test the effect of the McGEP on children's metacognitive skills (monitoring and control) and executive function skills (working memory, cognitive flexibility and inhibitory control) and to determine the permanence of this effect. Based on the findings obtained for the purposes of the study, the research results were formed.

Does the McGEP affect children's metacognitive skills? Is this effect permanent?

In the study, it was concluded that McGEP is an effective education program that improves children's metacognitive skills and that this effect is permanent. Flavell (1979) suggested that metacognition is skill that increases with age, but stated that it is possible to develop metacognitive knowledge and monitoring skills from an early age through systematic training programs. In this study, the McGEP was developed and it was concluded that this program improved children's metacognitive skills. It is so, the literature are examined, it has been proven that metacognition-based education has significant contributions to children's learning processes (Temur et al. 2019; Marić & Sakač, 2018; Serin & Korkmaz, 2018; Ganz & Ganz, 1990).

Table 5: Mann Whitney U Test Results Regarding the Difference Between the HTKS Post-test of the Study and Control Groups

		Group	*Rank Mean*	*Row Total*	*Average*	*Z*	*p*
HTKS	Level1	Study	18.77	281.5	19.00	-3.59	.000*
		Control	8.04	96.50	11.92		
	Level2	Study	18.27	274	16.00	-3.144	0.002*
		Control	8.67	104	9.00		
	Level3	Study	18.8	282	11.00	-3.538	.000*
		Control	8.00	96	3.50		
	Total	Study	18.93	284	46.00	-3.615	.000*
		Control	7.83	94	24.42		

*p<.05

Table 6: Friedman Test Results Regarding the Difference Between the HTKS Pre-test, Post-test and Follow-up Tests of Study Group

			Rank Mean	*Average*	*ss*	*χ2*	*p*	*Difference*
HTKS	Level1	Pre-test	1.10	13.07	1.38	23.143	.000*	1- 2**
		Post-test	2.30	19.00	1.64			1-3**
		Follow-up test	2.60	19.67	1.71			
	Level2	Pre-test	1.13	11.00	1.12	19	.000*	1-2**
		Post-test	2.27	16.00	1.37			1-3**
		Follow-up test	2.60	17.27	1.53			
	Level3	Pre-test	1.07	1.60	2.22	22.483	.000*	1-2**
		Post-test	2.20	11.00	2.46			1-3**
		Follow-up test	2.73	13.07	2.70			
	Total	Pre-test	1.07	25.67	0.52	22.351	.000*	1-2**
		Post-test	2.23	46.00	0.25			1-3**
		Follow-up test	2.70	50.00	0.39			2-3**

1: Pre-test, 2: Post-test, 3: Follow-up test
*p<.05 ** Wilcoxon Test Comparison

In their study, Ganz and Ganz (1990) found that metacognition-based education programs have significant effects on children's undertaking learning processes and developing their perception skills. Temur et al. (2019) emphasized that a well-developed metacognitive teaching approach can effectively develop children's problem-solving strategies, as well as allowing children to realize their strengths and weaknesses together. For this reason, they emphasized that children should be made aware of metacognitive processes. However, Whitebread et al. (2009) found that five-year-old children can exhibit verbal and nonverbal metacognitive responses during problem solving and regulating their emotional and affective states. Preschool children can apply simple strategic approaches to remember and recall items when tasks are meaningful to them. In this study, it was found that children used simple strategies to reach the result during the McGEP activities and suggested different strategies by guiding their friends. Similarly, Blöte et al. (1999), found that children's behavior was highly strategic and that they had the ability to transfer their strategies to new tasks. They also proved that four-year-old children can use some strategies and metacognitive processes in tasks involving puzzles (Sperling et al., 2000). At the same time, Larkin (2000) suggested that metacognitive knowledge, monitoring and individual control of learning can be achieved at an early age. In another study, it was found that five and six-year-old children were able to plan some mathematical tasks, monitor their own progress and express their thoughts about the task. In addition, they suggested that by asking children to justify their answers, they were able to monitor their progress (Tsamir & Tirosh, 2009). Marić and Sakač (2018) proved that preschool children have advanced metacognitive skills in different problem-solving tasks. They concluded that children who have declarative and procedural metacognitive knowledge, cognitive monitoring skills, and the ability to organize cognitive strategies are more successful in problem solving. In this study, it was concluded that the children to whom the McGEP was applied made significant improvements in the post-tests and follow-up tests compared to the pre-tests in the Train Track Task. Both the quality scores of the children and their monitoring and control skills, which are metacognitive skills, improved. While these skills improved, it was also found that the perseveration and distraction errors exhibited by the children during the task decreased significantly. Research in the literature supports these results. During the implementation of the McGEP, the reason for the significant increase in children's metacognitive skills may be the use of different and interesting concrete materials that children had not encountered before and the fact that the activity processes and the pre-prepared learning environments were interesting to children. Because the materials presented to children during the McGEP are materials that are suitable for modeling, which children were not familiar with before. With these materials, children were expected to use their visual perception skills to create desired pattern from materials such as many different cards, wooden blocks, and colored cubes. In addition, in this study, it was proved that the development in children's metacognitive skills was permanent. The persistence of these skills can be attributed to the fact that the researcher left all the educational materials used during the McGEP in the classroom. In addition, the developmental progress of the children from the beginning of the education process and their habitual use of the strategies used during the McGEP may also be the reasons for the improvement observed in the follow-up tests.

Does the McGEP affect children's executive function skills? Is this effect permanent?

In the study, it was concluded that the McGEP is an effective education program that improves children's executive function skills and that this effect is permanent. In the literature, research has been conducted on the relationship between executive functions and metacognition (Bryce et al., 2015; Chevalier & Blaye, 2016; Geurten et al. 2016; Marulis et al. 2016; Murray et al. 2016; Roebers et al. 2012; Whitebread, 1999). When comparing the relationship between executive functions and metacognition, it is necessary to examine the development of metacognition (Fernandez-Duque et al., 2000). In this study, the developmental characteristics of children's metacognitive skills were examined and McGEP was developed to develop these skills, and this program proved to be an effective program in developing children's executive function skills. Therefore, it can be said that supporting metacognitive skills improves children's executive function skills. In the literature, it has been stated that children's executive functioning skills improve significantly when they receive a training that supports metacognitive strategies (Çakıroğlu, 2007; Downing et al., 2007; Pilten, 2008; Zelazo, 2015). Bryce et al. (2015) proved that monitoring processes of five-year-old children are related to inhibitory control skills and working memory skills are related to control processes. This study also revealed the relationship between executive functions and perseveration and distraction errors. Therefore, these researchers evaluated both monitoring and control processes and revealed that both inhibitory control and working memory are related to these processes. In this study, it was also proved that both working memory and inhibitory control skills of the children improved significantly at the end of the process. In addition, it was found that metacognitive skills after the implementation of the McGEP increased significantly. On the other hand, the lack of metacognitive skills (perseveration and distraction) exhibited by the children decreased significantly. Therefore, the results of this study provide empirical evidence for the relationship structures obtained by Bryce et al. (2015) in their research. Roebers (2017) concluded that individual differences in working memory are related to metacognitive skills in both children and adults. Researchers working on this subject have identified small but significant relationships between working memory and metacognition, explaining 5% to 10% of the variance. When both monitoring and control processes from metacognitive skills were evaluated in the studies, the results proved that there is stronger relationship between working memory and control skill than between working memory and monitoring skill (Bryce et al. 2015; Roebers et al. 2012). The results of studies reveal that working memory is frequently associated with metacognitive skills. In this study, it was concluded that there were significant increases in the working memory performance of the study group compared to the control group. The children to whom the McGEP is implemented need to plan what they will do in the learning process, sort out what is expected of them in the activities and keep them in mind to apply them, remember what needs to be done when evaluating the strategies used by their friends and themselves, and put this information to work. In these cognitive processes, children actively used working memory. In fact, as a result of working memory measurements, it was found that children in the study group showed significant improvements in both verbal and visual memory sub-dimensions, while children in the control group generally showed improvement in the verbal memory sub-dimension. When this result was evaluated, it was thought that the use of geometry as tool in the McGEP and the frequent use of visual and concrete materials was an important factor. Friso-van den Bos et al. (2013) found that working memory is consistent predictor of mathematics and emphasized the strong relationships between visual and auditory senses. Similarly, Reuhkala (2001) found strong relationship between children's visual working memory and their math performance. Therefore, in this study, it can be said that the inclusion of geometry skills, one of the subfields of mathematics, in the McGEP also contributed to the development of executive functions. In addition to working memory, it was also concluded that the McGEP significantly increased children's inhibitory control and cognitive flexibility skills. During the McGEP activities, the children expressed out loud how they would proceed, suggested different strategies for what their peers should do, and decided between several solutions by trying them out. In these processes, children used their cognitive flexibility skills. In addition, they kept in mind the procedures they had planned and used inhibitory control skills to implement them, ignoring processes that were outside their goals. Souchay and Isingrini (2004) proved that strategy use is an indicator of metacognitive control processes and that cognitive flexibility performance is related to strategy use. Geurten et al. (2016) aimed to investigate whether and how executive functions affect metacognition performance and found significant links between verbal fluency and working memory and metacognition measures in 6- and 9-year-old children. Similarly, Bryce et al. (2015) reported correlation of $r = 0.35$ between inhibitory control and monitoring in 5- and 7-year-old children. However, Roebers et al. (2012) found that monitoring was not related to inhibitory control skills. Nevertheless, the results of several studies have reported baseless links between cognitive flexibility and metacognitive monitoring and control in elementary school children (Roebers et al. 2012; Spiess et al. 2016). Moreover, some other studies have reported non-significant links between these two constructs in children (Geurten et al., 2016). These variable findings in the literature are attributed to the use of different assessment tools to assess executive function skills and metacognitive skills. The executive function and metacognition tasks used in the studies may trigger non-metacognitive processes such as children's domain-specific knowledge, immediate motivation, and familiarity with the task. Another factor is that a single executive function component or metacognition aspect cannot be measured in isolation. Because different sub-processes within a concept are strongly intertwined and seen as mutually interdependent (Roebers, 2017). The variable results obtained from these studies in the literature reveal that in order to better understand the relationship structure between executive function and metacognitive skills, studies designed with various methodologies using different measurement tools and different evaluation methods are needed. Therefore, this study was conducted in intervention design and makes important contributions to the relevant literature to understand the relationship between metacognitive and executive functioning skills.

Limitations and Recommendations

The results of the study were informative in terms of developing metacognitive skills at an early age and including them in learning processes. However, there are some limitations in measuring metacognitive skills at early ages (Whitebread et al., 2009). In this study, in order to evaluate metacognitive skills, the verbal and non-verbal responses of children during the problem solving task (Train Track Task) were observed and the frequency rates were compared. In the applied task, children were not encouraged to express their thinking processes verbally due to the implementation protocol of the task, so some children's thoughts during the task were not revealed. For this reason, in future studies, assessment methods that encourage both verbal and non-verbal responses can be used to evaluate children's metacognitive skills in a holistic manner. Another limitation is the use of different assessment tools for each sub-component when assessing children's executive function skills. This situation caused the researcher to have difficulty in collecting data. For this reason, in future studies, holistic assessment tools that include all sub-components of executive functions can be developed. Roebers (2017) proposed an integrative structure for metacognition and executive functioning skills. She emphasized the importance of focusing on conceptual, theoretical and empirical similarities rather than distinctions between these two constructs. As a result of this study, it was concluded that the McGEP improved children's executive functioning skills. In order to examine the reciprocal effect between these two constructs, future studies may examine the effect of educational programs that support executive functions on metacognitive skills.

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References

Allan, D. M., Allan, N. P., Lerner, M. D., Farrington, A. L., & Lonigan,C. J. (2015). Identifying unique components of preschool children's self-regulatory skills using executive function tasks and continuous performance tests. *Early Childhood Research Quarterly*, 32, 40–50.

Anderson, V., Jacobs, R., & Anderson, P. (2010). *Executive functions and the frontal lobes: A lifespan perspective.* New York, NY: Psychology Press.

Biryukov, P. (2004). Metacognitive aspects of solving combinatorics problems. *International Journal for Mathematics Teaching and Learning*, 1-19.

Blair, C., & Diamond, A. (2008). Biological processes in prevention andintervention: The promotion of self-regulation as a means of preventing schoolfailure. *Development and Psychopathology*, 20, 899–911.

Blakey, E. & Spence, S. (1990). Developing Metacognition. ERIC Digest. Retrieved from EBSCOhost, https://eric.ed.gov/?id=ED327218 adresinden erişilmiştir.

Blöte, A. W., Resing, W. C. M., Mazer, P., & Van Noort, D. A. (1999). Young children's organizational strategies on a same-different task: A microgenetic study and a training study. *Journal of Experimental Child Psychology*, 74, 21–43

Brown, A. L. (1987). Metacognition, executive control, selfregulation, and other even more mysterious mechanisms, In Weinert, F.E. Kluwe, R.H. (eds.) *Metacognition, motivation and understanding.* Hillsdale, NJ: Lawrence Erlbaum Associates

Bryce, D. & Whitebread, D. (2012). The development of metacognitive skills: Evidence from observational analysis of young children's behavior during problem-solving. *Metacognition and Learning, 7*(3), 197-217.

Bryce, D., Whitebread, D., & Szücs, D. (2015). The relationships among executive functions, metacognitive skills and educational achievement in 5 and 7year-old children. *Metacognition and Learning*, 10, 181–198.

Büyüköztürk, Ş., K. Çakmak, E., Akgün, Ö. E., Karadeniz, Ş. & Demirel, F. (2014). *Bilimsel araştırma yöntemleri.* Ankara: Pegem Akademi.

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology*, 28, 595–616.

Chatzipanteli, A., Grammatikopoulos, V., & Gregoriadis, A. (2014). Development and evaluation of metacognition in early childhood education. *Early Child Development and Care, 184*(8), 1223-1232.

Chevalier, N., & Blaye, A. (2016). Metacognitive monitoring of executive control engagement during childhood. *Child Development,* 87, 1264–1276.

Chevalier, N., Martis, S. B., Curran, T., & Munakata, Y. (2015). Metacognitive processes in executive control development: The case of reactive and proactivecontrol. *Journal of Cognitive Neuroscience*, 27, 1125–1136.

Clements, D. H., Sarama, J., & Germeroth, C. (2016). Learning executive function and early mathematics: Directions of causal relations. *Early Childhood Research Quarterly*, 36, 79-90.

Cooper-Kahn, J., & Foster, M. (2013). *Boosting executive skills in the classroom: A practical guide for educators*. San Francisco, CA: Jossey-Bass

Costa, A. (1984). Mediating the Metacognitive, *Educational Leadership, 42*(3), 57-63.

Coughlin, C., Hembacher, E., Lyons, K. E., & Ghetti, S. (2015). Introspection on uncertainty and judicious helpseeking during the preschool years. *Developmental Science*, 18, 957–971.

Cragg, L., & Nation, K. (2007). Self-ordered pointing as a test of working memory in typically developing children. *Memory, 15*(5), 526-535.

Çakıroğlu, A. (2007). Üstbilişsel strateji kullanımının okuduğunu anlama düzeyi düşük öğrencilerde erişi artırımına etkisi. Doktora tezi, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara.

DeMarie, D., Miller, P. H., Ferron, J., & Cunningham, W. R. (2004). Path analysis tests of theoretical models of children's memory performance. *Journal of Cognition and Development*, 5, 461-492.

Diamond, A. (2013). Executive functions. *Annual Review Of Psychology*, 64, 135–168.

Downing, K., Ho, R., Shin, K., Vrijmoed, L., & Wong, E. (2007). Metacognitive development and moving away. *Educational Studies, 33*(1), 1-13.

Dunlosky, J., & Thiede, K. W. (2004). Causes and constraints of the shift-to-easier-materials effect in the control of study. *Memory & Cognition*, 32, 779-788.

Ergül, C., Yılmaz, Ç. Ö., & Demir, E. (2018). 5-10 yaş grubu çocuklara yönelik geliştirilmiş çalışma belleği ölçeğinin geçerlik ve güvenirliği. *Eğitimde Kuram ve Uygulama, 14*(2), 187-214.

Fernandez-Duque, D., Baird, J. A., & Posner, M. I. (2000). Executive attention and metacognitive regulation. *Consciousness and Cognition*, 9, 288–307.

Fitzpatrick, C., McKinnon, R. D., Blair, C. B., & Willoughby, M. T. (2014). Do preschool executive function skills explain the school readiness gap between advantaged and disadvantaged children? *Learning and Instruction*, 30, 25-31.

Flavell, J. H. (1976). Metacognitive Aspects of Problem Solving, in L. B. Resnick(Ed.). *The Nature of Intelligence*, pp. 231-235, Hillsdale, N. J,: Lawrance Erlbaum.

Flavell, J.H. (1979). Metacognitive and Cognitive Monitoring. *American Psycholist*, 34, 96-911.

Flavell, J. H. (1987). Speculation about the nature and development of metacognition. F. E. Wernert ve R. H. Kluwe (Ed.). *Metacognition, motivation and understanding* (s. 21-29). Hillside, NJ: Lawrence Erlbaum Associates.

Friso-van den Bos, I., van der Ven, S. H., Kroesbergen, E. H., & Van Luit, J. E. (2013). Working memory and mathematics in primary school children: A meta-analysis. *Educational Research Review*, 10, 29–44.

Gandolfi, E., Traverso, L., Zanobini, M., Usai, M. C., & Viterbori, P. (2021). The longitudinal relationship between early inhibitory control skills and emergent literacy in preschool children. *Reading and Writing*, 1-25.

Ganz, M. N. & Ganz, B. C. (1990). Linking metacognition to classroom success. *The Highschool Journal*, *73*(3), 180-185.

Gashaj, V., Oberer, N., Mast, F. W. & Roebers, C. M. (2019). The relation between executive functions, fine motor skills, and basic numerical skills and their relevance for later mathematics achievement. *Early Education and Development*, *30*(7), 913-926.

Geary, D. C., Hoard, M. K., Nugent, L., & Byrd-Craven, J. (2008). Development in number line representations in children with mathematical learning disability. *Developmental Neuropsychology*, 33, 277–299.

Geurten, M., Catale, C., & Meulemans, T. (2016). Involvement of executive functionsin children's metamemory. *Applied Cognitive Psychology*, 30, 70–80.

Hacker, D. J. & Dunlosky, J. (2003). Not all metacognition is created equal. *New Directions for Teaching and Learning*, 95, 73-79.

Hattie, J. (2012). Visible Learning for Teachers: Maximising Impact on Learning. Abingdon: Routledge.

Heibel-Witte, V. K. (2016). *The relation between motor skill performance and inhibitory control in five and six-year-old children*. Michigan State University.

Hughes, C., & Ensor, R. (2008). Does executive function matter for preschoolers' problem behaviors?. *Journal of Abnormal Child Psychology*, 36, 1–14.

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia*, 44, 2017–2036.

Jacques, S. & Zelazo, P. D. (2001). The Flexible Item Selection Task (FIST): A Measure of Executive Function in Preschoolers. *Developmental Neuropsychology, 20* (3), 573– 591.

Jager, B., Jansen, M. & Reezigt, G. (2005). The development of metacognition in primary school learningenvironments. *School Effectiveness and School Improvement*, 16, 179-196.

Kao, Y. C., Davis, E. S., & Gabrieli, J. D. (2005). Neural correlates of actual and predicted memory formation. *Nature Neuroscience*, 8, 1776-1783.

Kovac-Cerovic, T. (1996). *How can we as parents and educators foster metacognitive development?* Childhood Education: International Perspectives.

Larkin, S. (2000). *How can we discern metacognition in year one children from interactions between students and teacher.* Paper presented at the ESRC Teaching and Learning Research Programme Conference.

Lehto J.E., Juuj¨arvi P., Kooistra L. & Pulkkinen L. (2003). Dimensions of executive functioning: evidence from children. *Br. J. Dev. Psychol*., 21, 59–80

Lin, X. (2001). Designing metacognitive activities. *Educational Technology Research and Development*, 49, 23–40.

Lyons, K. E., & Ghetti, S. (2013). I don't want to pick! Introspection on uncertainty supports early strategic behavior. *Child Development, 84*(2), 726–736.

Malone, S. A., Pritchard, V. E., Heron-Delaney, M., Burgoyne, K., Lervåg, A., & Hulme, C. (2019). Data on numerosity discrimination, inhibition and arithmetic during the early school years. *Data in brief*, 25, 104062.

Marić, M., & Sakač, M. (2018). Metacognitive components as predictors of preschool children's performance in problem-solving tasks. *Psihologija, 51*(1), 1-16.

Marulis, L. M., Baker, S.T. & Whitebread, D. (2020). Integrating metacognition and executive function to enhance young children's perception of and agency in their learning. *Early Childhood Research Quarterly*, 50, 46-54

Marulis, L. M., Palincsar, A. S., Berhenke, A. L., & Whitebread, D. (2016). Assessing metacognitive knowledge in 3–5 year olds: The development of a metacognitive knowledge interview (McKI). *Metacognition and Learning*, 11,1–30.

Mayer, R.E. (1998). Cognitive, metacognitive and motivational aspects of problem solving. *Instructional Science*, 26, 49-63.

Miyake, A., Friedman, N., Emerson, M., Witzki, A., & Howerter, A. (2000). The unity and diversity of executive functions and their contributions to complex 'frontal lobe' tasks: A latent variable analysis. *Cognitive Psychology*, 41, 49-100.

Murray, J., Theakston, A., & Wells, A. (2016). Can the attention training technique turn one marshmallow into two? Improving children's ability to delaygratification. *Behaviour Research and Therapy*, 77, 34–39.

Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. In G. Bower (Ed.), *The psychology of learning and motivation* (Vol. 26). New York: Academic.

Pekince, P. & Avcı, N. (2021). *Tren rayı görevinin Türkçe geçerlik güvenirlik çalışması.* Genç Araştırmacılar Kongresi'nde sunulmuş bildiri, Gazi Üniversitesi, Ankara.

Pilten, P. (2008). *Üst biliş stratejilerinin ilköğretim beşinci sınıf öğrencilerinin matematiksel muhakeme becerilerine etkisi.* Doktora Tezi, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara.

Ponitz, C. E. C., McClelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly, 23*(2), 141-158.

Pressley, M., Forrest-Pressley, D., Elliot-Faust, D., & Miller, G. E. (1985). Children's use of cognitive strategies, how to teach strategies, and what to do if they can't be taught. In M. Pressley & C. J. Brainerd (Eds.), *Cognitive learning and memory in children* (pp. 1-47). New York, NY: Springer-Verlag.

Reuhkala, M. (2001). Mathematical skills in ninth-graders: Relationship with visuo-spatial abilities and working memory. *Educational Psychology, 21*(4), 387–399.

Roebers, C. M. (2017). Executive function and metacognition: Towards a unifying framework of cognitive self-regulation. *Developmental Review*, 45, 31–51.

Roebers, C. M., Cimeli, P., Röthlisberger, M., & Neuenschwander, R. (2012).Executive functioning, metacognition, and self-perceived competence inelementary school children: An explorative study on their interrelations andtheir role for school achievement. *Metacognition and Learning*, 7, 151–173.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science, 26* (12), 113-125.

Serin, M. K., & Korkmaz, İ. (2018). İşbirliğine dayalı ortamlarda gerçekleştirilen üstbilişsel sorgulama temelli öğretiminilkokul 4. sınıf öğrencilerinin matematiksel problem çözme becerilerine etkisi. *Elementary Education Online, 17*(2).

Sezgin, E. (2016). *Çocukların davranışsal öz düzenleme becerilerine oyun temelli eğitimin etkisinin incelenmesi.* Doktora Tezi, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü.

Sperling, R. A., Walls, R. T., & Hill, L. A. (2000). Early relationships among self-regulatory constructs: theory of mind and preschool children's problem solving. *Child Study Journal, 30*(4), 233–251.

Spiess, M. A., Meier, B., & Roebers, C. M. (2016). Development and longitudinal relationships between children's executive functions, prospective memory, and metacognition. *Cognitive Development*, 38, 99-113.

Şahin, G. (2015). *Okul öncesi çocukların yürütücü işlevlerinin ve duygu düzenleme becerilerinin bağlanma örüntüleri açısından incelenmesi*. Doktora Tezi, Selçuk Üniversitesi, Sosyal Bilimler Enstitüsü.

Tabachnick, B.G. & Fidell, L.S. (2013). *Using Multivariate Statistics.* Boston: Pearson.

Temur, Ö. D., Özsoy, G., & Turgut, S. (2019). Metacognitive instructional behaviours of preschool teachers in mathematical activities. *ZDM, 51*(4), 655-666.

Tsamir, P., & Tirosh, D. (2009). Affect, subject matter knowledge and pedagogical content knowledge: The case of a kindergarten teacher. Beliefs and attitudes in mathematics education. *New Research Results*, 19-32.

Watson, S. M., & Westby, C. E. (2003). Strategies for addressing the executive function impairments of students prenatally exposed to alcohol and otherdrugs. *Communication Disorders Quarterly*, 24, 194–204.

Whitebread, D. (1999). Interactions between children's metacognitive abilities, working memory capacity, strategies and performance during problem-solving. *European Journal of Psychology of Education*, 14, 489–507.

Whitebread, D., Coltman, P., Pasternak, D., Sangster, C., Grau, V., Bingham, S. & Demetriou, D. (2009). The development of two observational tools for assessing metacognition and self-regulated learning in young children. *Metacognition and Learning, 4*(1), 63-85.

Zelazo, P. D. (2015). Executive function: Reflection, iterative reprocessing, complexity, and the developing brain. *Developmental Review*, 38, 55-68.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into Practice*, 41(2), 64–70.