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Research Article

Mitigate negative beliefs about math: A different experience for children and teachers in early math

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This study investigated the effect of the use of content-specific material-based activities on children's mathematical skills, and changes in emotions for both sides with the help of math workstations to serve as responsive partners in delivering quality mathematics education to children and teachers. A total of 20 female kindergarten teachers and 625 children (female= 393, male=232, M = 64.57 months) studying in classes with disadvantages pertaining to materials participated in the study. The study used a fully mixed sequential equal status design, and quantitative data was analyzed using ANOVA and multilevel regression, while inductive content analysis was used to analyze qualitative data. The study found that teachers' development of facilitating alternative perspectives towards mathematics mitigated negative beliefs related to emotions arising from teachers' and children's negative experiences with mathematics. This study re-emphasizes the significance of emotional circumstances for learning mathematics in early childhood education, and teachers need game-based, effective, and innovative pedagogical approaches without prioritizing academic concerns.

Keywords: Early math skills; Classroom environments; Math work stations; Emotional circumstances; Teacher-child interactions; Multilevel regression analysis

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1. Introduction

The mathematical concepts that children learn while interacting with each other through games form the basis of their future learning. However, real learning happens when teachers associate mathematical situations with children's interests (Connor et al., 2006). In this process, expanding informal knowledge through interactions involving more formal mathematical language is crucial. If young children's informal learning about math during early childhood education is not integrated with formal math learning during the early stages of education, it can create gaps in their math knowledge that may be difficult to address later on, according to a report published by the National Association for the Education of Young Children [NAEYC] and National Council of Teachers of Mathematics [NCTM] (2010). These learning gaps need to be addressed before elementary school; only then can children develop a conceptual basis to support later learning (Baroody et al., 2006).

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For developing math skills, which have an important place in children's future lives, the ECE curriculum and social and physical environmental conditions should strongly highlight mathematics. Therefore, both the NCTM and the NAEYC consider ECE vital in terms of mathematical skill development (Baroody et al., 2006). Recent studies show that school entry-level math skills have more significance in predicting subsequent school success than reading-writing preparation, attention, and social development skills (Duncan et al., 2007). Although mathematics-oriented activities have such predictive power for the future, children in the ECE period do not engage enough in such activities at home or in school (Siegler & Ramani, 2009). In fact, children in ECE institutions receive only half as much mathematics education compared to reading-writing preparation activities (National Research Council [NRC], 2009). Furthermore, mathematics education is provided only during 2.5% of the day in classrooms (Stipek et al., 2012). The reason for this situation could be the unwanted social (i.e., teacher, peers, and parents) and physical learning environments triggered by teachers' negative beliefs and attitudes and mishandling of the curriculum (NRC, 2009).

1.1. Key Principles of Mathematics Teaching

Although most ECE teachers feel comfortable with early reading and writing subjects, they do not consider themselves mathematics educators. This may be because of the emphasis in early education on developing reading and writing (NRC, 2009) and widespread negative attitudes toward mathematics content and its teaching among ECE teachers (Lee & Ginsburg, 2009). Mathematics anxieties, fostered by negative, dull, unproductive experiences in the past, prevent most teachers from teaching mathematics (Philipp, 2007). However, although ECE teachers do not need to be mathematicians, they should know how to convey the content they are supposed to teach (Lee & Ginsburg, 2009). Teachers develop gamified, entertaining mathematics content and use varied methods for transferring lesson contents (Vogt et al., 2018). ECE teachers may have misconceptions about math, which could limit their instruction to only covering basic concepts such as numbers and shapes for children. Therefore, there is a continuing concern ECE leaves children with incomplete learning in mathematics (NAEYC/NCTM, 2010).

Teachers have several options to change their negative attitudes. When teachers try different approaches, they can see that the materials and teaching techniques that attract children's attention also change their own negative attitudes and excite them. Including mathematics in daily life is a way to make it more prominent (McCray & Chen, 2012). Having a good grasp of math concepts is essential for a child's ability to comprehend the curriculum with ease. Acknowledging that games are a natural way for children to make sense of their world, teachers should design the mathematics education process in an exciting, engaging, and creative way (Penttinen et al., 2020). For the implementation of this option, materials that encourage children to think mathematically and support peer interaction/education should be used frequently in activities. Children can deal with mathematical concepts and operations in their daily activities only in such environments (NAEYC/NCTM, 2010).

In educational settings that include mathematical games, young children can apply their knowledge to new situations. They can reflect on the strategies their peers use to solve similar problems and learn easily. Contrary to popular belief, children can quickly advance in understanding mathematical concepts by using numerical relationships, sets, measurements, and comparison strategies effectively. Therefore, teachers must develop an educational environment where they can continuously evaluate children through materials and interactions (Pyle & DeLuca, 2017). Educators should be aware of children’s mathematical experiences, and the type of mathematical experiences their physical and social educational environments inspire (Tudge & Doucet, 2004).

1.2. Supporting Mathematics Learning through Materials and Language

Although children can learn from games, teachers should not assume that mathematics learning will occur spontaneously. Education should be planned based on and in line with teaching contents. For example, materials and toys that are likely to inspire mathematical situations can be carefully brought together and placed in math stations in the classroom. This way, teachers can produce scenarios that introduce and support mathematical concepts while guiding the next game according to children's needs.

Studies indicate that the amount of math-related talk of both teachers (Klibanoff et al., 2006) and parents are significantly associated with children's mathematical learning (Gurgah Ogul & Aktas Arnas, 2020). Teachers can introduce math words in engaging and meaningful contexts through the classroom conversations that children join. They can incorporate into game experiences the types of mathematical questions that children need to understand in more formal educational settings in the future (Cohrssen & Niklas, 2019). Thus, classroom environments where concepts are always retained and that support active learning can be designed and included in the interaction. In many interactions that children have with adults through materials, there is math-talk potential (Uscianowki et al., 2020). Although this is a known fact, many ECE teachers hesitate to talk about mathematical content, dislike mathematics, or do not realize the potential of mathematics-related discussions in their classes. It is unfortunate to miss out on such opportunities. However, teachers' negative beliefs about mathematics (i.e., tendency to avoid talking about the content) may change with need-oriented training and practices (Ginsburg et al., 2008). If teachers want to link mathematics with everyday dialogues, it may be helpful to include conversation openers, such as math work stations.

1.3. Defining Math Work Stations [MAWS]

MAWS are areas associated with mathematics in the classroom, where children are expected to collaborate with peers and use teaching materials to explore or expand their mathematical thinking (Diller, 2011). The activities and practices performed in MAWS allow children to improve their mathematical perceptions by reinforcing previously acquired knowledge. While MAWS offer children the opportunity to independently materialize mathematical content, they also present the opportunity to rationalize individually or in groups between the subjects. They allow children to make connections through substantial mathematical interactions with peers and adults. In learning environments where teachers have less control over their students, they can still gain valuable insights into their students' learning by actively participating in activities and observing them closely. Through this type of observation, teachers can establish closer relationships with students, communicate with them more intentionally, and provide more accurate evaluations of their progress (Pyle & DeLuca, 2017). Additionally, such areas, equipped with easy-to-use mathematical materials in transitions between activities, can positively affect learning conditions because they increase effective communication in the classroom (Karademir & Akman, 2021).

According to several studies and international reports, there is a need for social and physical environments where mathematical language is used with meaningful content and where early period mathematics rules can be introduced for children through their informal knowledge (NAEYC/NCTM, 2010). In the mathematical achievements updated in 2013 in Turkey's ECE curriculum, the emphasis on children's requirement to be active in processes such as planning, implementation, research, inquiry, discussion, and production by being aware of what is happening around them confirms this need (Ministry of National Education [MoNE], 2013). However, in Turkey's ECE system, learning stations where content-specific mathematical materials are presented together are not used in any official state institution. Considering that ECE quality is negatively affected, especially in classrooms with disadvantaged environments and that there are issues regarding materials, there is a need for studies that explore appropriate mathematical learning opportunities according to children's individual needs. In this context, it is crucial to determine how using purposefully developed materials for classrooms affects children's math skills.

1.4. Current Study

Previous studies have shown that physical learning environments in ECE fall short of expectations in terms of quality, and this situation negatively affects children in particular (Ozyurek & Kilinc, 2015). Some studies note that teachers do not incorporate mathematics as much as is necessary in the teaching process because of emotional or pedagogical reasons and those them mostly perceive it as an inefficient desk-bound activity (Emen & Aslan, 2018). Few studies have implemented short-term intervention programs (Erdogan et al., 2017) enriched with materials to improve adverse physical environmental conditions for early mathematical skill development and recorded improvements in children's skills. Boz et al. (2020) conducted a study with 45 children, revealing that the learning environment supported by manipulative materials outside the classroom had a positive effect on children's math skills. This study differs from the extant literature in several ways. First, it provided equal opportunities for children. The study not only improved the physical education environment of the classroom but also supported teachers' pedagogical content knowledge, taking into account the social learning environment. Second, it used MAWS, which was developed for the first time in Turkey and included in ECE, and had both children and teachers adopt different roles. Third, it combined relational and experimental methods to examine how the nature of teacher–child and peer interactions in the classroom can contribute to mathematical skills over time. Fourth, unlike most studies, it describes the impact of the intervention, which views teachers as responsive partners to children, on mathematical interactions. Finally, the study shows how ECE teachers can successfully change their mathematics teaching strategies despite the constraints of the public school system.

This study examined the effect of MAWS, which consists of content-specific developed materials, on the mathematical skills of children in the ECE classrooms where they are set up and the changes that occur in the process. The study also fills the gaps in the literature by examining the various situations that arise during interactions between children and teachers in improved social and physical conditions. The research questions of this study are as follows:

RQ 1) In the experimental group classes, what is the effect of the purposefully used MAWS on children's math skills?

RQ 2) In what ways do the variables related to children and teachers in the groups using MAWS affect children's math skills?

RQ 3) What are the experiences of teachers and children on using MAWS?

2. Method

2.1. Research Design

This study used a fully mixed sequential equal status design, which can be adopted in quasi-experimental studies (Leech & Onwuegbuzie, 2009). For quantitative testing, data on children's mathematical skills were obtained with the Test of Early Mathematics Ability, Third Edition (TEMA-3) before and after the intervention (Experimental). In the quantitative section, the variables that led to the increase in the TEMA-3 posttest scores of the children in the experimental group were determined (Relational). The study examined in depth through qualitative methods whether there was any difference in children's educational lives and the professional competencies of the teachers because of being provided with supportive materials and resources.

The researchers ran a project before the intervention to equip the MAWS used in the experimental groups. A group of 65 people, including the researchers, and 6 of the teachers in the experimental groups, participated in a 6-week training. The training introduced the activity planning, development, implementation, and evaluation steps involved in the use of the mathematics material. Of the 20 ECE teachers who participated in this study voluntarily, 10, including 6 teachers who participated in the training project, were assigned to the experimental groups using purposeful sampling, and the other 10 were assigned randomly to the control groups. After completing the pretests, children (n = 318) in classes with MAWS participated in the intervention for 18 weeks. In addition to children's mathematical knowledge and skills, the behaviors of the teachers in the experimental groups were examined in detail through field observations, and video recordings conducted periodically during the intervention period.

2.2. Study Procedures

In line with the recommendations of NAEYC (2010), this national-scale project helps teachers provide different learning environments to children; aid children in gaining different perspectives and developing their creativity; and make simple, effective, inexpensive manipulative mathematics materials through appropriate experiences. For this purpose, teachers received training on the production and use of mathematical materials to improve numeracy and arithmetic skills with unstructured ordinary materials. Apart from the project training, six teachers who were expected to participate in this study were provided 10 hours of special training over five sessions to improve their professional competency in ECE mathematics teaching methods and techniques. The study attempted to improve teachers' knowledge, skills, behaviors, and attitude levels with regard to mathematics education. The five sessions focused on specific strategies for the use of MAWS, which included discussing, developing, and adapting the mathematical language; activity ideas; and classroom application.

The 300 materials (the same set of 30*10 different classes) that were developed after the project ended were placed in 10 classrooms of 4 kindergartens at the beginning of Fall semester of the 2018–2019 academic year. Four experimental group teachers did not participate in the previous project. (In this study, the situation of the teachers not participating in the project training directly was used to comparatively interpret the effects of the project on the material usage skills of the teachers in the experimental groups and their behaviors in the process.) To ensure the uniformity of activities in experimental groups, a user manual including the material's title, targeted mathematical concepts and skills, and properties of the equipment used in the production of each material developed was prepared. The manuals were delivered to all teachers in the experimental groups with the MAWS. There was no intervention in the 10 control group classes; they continued standard curriculum education and the activities determined by the Ministry of National Education (MoNE). After the training, the field team performed observation recording, coding, and scale application work with a different group of children independent of this study.

2.3. Participants

The research activity was conducted in 20 classrooms (10 experimental groups, 10 control groups) of 4 formal kindergartens affiliated with the MoNE, of which 2 offer full-day education services and 2 offer half-day services. The teachers (n = 20, female = 20) of the classes where the study was conducted and a total of 625 (393 female and 232 male) children aged 59–75 months (M = 64.57, SD = 3.10) constituted the participant group. The teachers' education levels were as follows: master's (0.3%), undergraduate (70.6%), and open education (29.1%). Their professional experience varied between 2 and 23 years (M = 10.94, SD = 6.59). All teachers who participated in the study reported that their classrooms faced disadvantages in terms of educational materials.

2.4. Measures

2.4.1. Test of Early Mathematics Ability-3 (TEMA-3)

TEMA-3 was developed by Ginsburg and Baroody (2003) and adapted to Turkish by Erdogan (2006). It consists of 72 items in a standardized norm-referenced structure and evaluates the mathematical concepts informally and formally acquired by children between the ages of 3 and 8 years and 11 months. This test, widely used in ECE research, is used to measure mathematical skills. This test evaluates children's ability to show numbers with their fingers, read and write numbers, and their skills in addition and subtraction operations. The test yields scores that are adjusted for the age of the child. An increase in the child's score indicates improvement in their math skill. The test is administered to each child individually, and the assessment takes approximately 30–35 minutes. While the internal consistency coefficient of the test was $\alpha = .94$, the test–retest reliability coefficient was r = .82 (Ginsburg & Baroody, 2003). The translation and adaptation study conducted by Erdogan (2006) provided the content validity of TEMA-3, and the criterion validity study proved that TEMA-3 successfully distinguished between children with good and weak math skills. While the internal consistency reliability coefficient (KR-20) was $\alpha = .92$, the test–retest reliability coefficient was calculated as r = .90.

As stated in Educational and Psychological Test Standards, scales used in research must be valid and reliable (AERA, APA & NCME, 1999). Within the scope of this study, a confirmatory factor analysis (CFA) was conducted on the pretest data to determine the structural validity of TEMA-3. According to the CFA results, the fit indexes of the single factor structure were found to be good [$\chi^2 = 311.18$, RMSEA = .07, SRMR = .08, GFI = .99, IFI = .90, CFI = .90]. While the internal consistency coefficient for the pretest was $\alpha = .80$, it was $\alpha = .88$ for the posttest. Based on the criteria specified by George and Mallery (2019), the scores obtained from the pretest and posttests were reliable at a good level. To determine the inter-rater reliability of TEMA-3, a trial application was conducted on 24 children, and the consistency between the scores of the responsible researcher and 5 expert raters were determined separately by calculating the Kappa statistics. The Kappa coefficients calculated for each item vary between $\kappa = .75$ and $\kappa = 1.00$. According to the level of adjustment specified by Landis and Koch (1977), it was concluded that each item's consistency between raters was high.

2.4.2. Video recordings

Each participating child and teacher in the experimental groups were recorded for 1800 (100 min*18 weeks) minutes in 2 periods (days) of 50 min while using MAWS during the 18-week research process. The records obtained by the researchers were organized by focusing on the behaviors of both children and teachers during the use of MAWS.

The first author of this article and a research assistant examined the edited records and entered them into the checklists. Items based on ECE achievements and indicators prepared by MoNE were used to monitor children's skill development. The researchers classified the children's interest (duration of use) in MAWS materials as low, medium, and high. Children's continuous use of and physical contact with the material and the inclusion of the materials in their games indicated a high level of interest. The sections where children interacted with materials for a short time; used, examined, and left them occasionally; and left the station to head to different activities indicated a medium level of interest. The sections where the children only observed the station without physically interacting with the materials indicated a low level of interest. Then, two people from the field team encoded each video recording independently, and the findings were compared with the first encodings. The coefficient of Krippendorff's alpha (Krippendorff, 1995), calculated for inter-rater reliability and consistency, was found to be high ($\alpha = .88$).

2.4.3. Teacher–child and peer math interactions

Through the edited video the coders rated the teacher–child and peer math interactions during the use of MAWS as low, medium, and high. Continuous mathematical interactions established by the participants in the experimental groups were determined as high-level interactions with verbal or physical contact. The periods in which the participants entered and exited mathematical interactions, guided and directed each other, and then left were described as medium-level interactions. The parts in which the participants only observed and did not interact were described as low-level interactions. To determine the level of interaction between children and teachers and children, the field team encoded each video record independently, and the Krippendorff's alpha (Krippendorff, 1995) coefficient, calculated for the inter-rater reliability among evaluators, was found to be high ($\alpha = .87$).

2.5. Data analysis

2.4.1. Quantitative analysis

Because pretest scores were used in the validity study within the scope of this study, first, missing data, multivariate normality, linearity, and multicollinearity assumptions were tested (Tabachnick & Fidell, 2013). Further, whether the construct validity of the one-dimensional TEMA-3 was ensured was examined using CFA (Brown, 2015). Afterwards, the normality and homogeneity assumptions of variances regarding the TEMA-3 pretest and posttest scores were tested (Field, 2009). After obtaining the mean and standard deviations of the TEMA-3 scores of children in the experimental and control groups, a one-way between-group analysis of variance was conducted to analyze whether there was a significant difference between the pretest scores of the children (Howell, 2013). Then, a mixed-design ANOVA was performed to determine whether the change between the repeated measurements showed a significant difference compared to the experimental and control groups (Field, 2009). To evaluate how relevant the significant differences are in practice, the partial eta-squared effect size coefficient was interpreted (Richardson, 2011).

Data were collected from children and teachers in different preschool educational institutions. In the literature, it is emphasized that if data are collected from children from different schools and classes, the characteristics of both the children and teachers should be taken into account. Children in the same class exhibit more similar characteristics compared to children in other classes because of the impact of their preschool teachers (Leeuw & Meijer, 2008). In this context, within the scope of this study, to determine the variables that predict the posttest scores of the children in the experimental groups, the variables related to children and teachers were examined together and the multilevel regression model (Hox & Roberts, 2011) was established and analyzed.

The posttest scores of children in experimental groups were estimated as follows: gender (1 girl, 2 boy); age (month); mother's educational level (1 primary school, 2 secondary schools, 3 high school, 4 university); father's educational level (1 secondary school, 2 high school, 3 university); children's interest in materials (1 low, 2 medium, 3 high); peer interaction level (1 low, 2 medium, 3 high); teacher's experience (years); time for which MAWS was placed in the classroom (hours); status of teachers' participation in the project (1 did not participate, 2 participated); and teacher–child interaction levels (1 low, 2 medium, 3 high). Whether there were missing data before the analysis, sample size of teacher–child interaction levels, homogeneity of the variances, and independent and normal distribution requirements of errors were examined, and the analysis was conducted after establishing assumptions. All statistical analyses in the study were performed at a 0.05 significance level with JASP 0.10.2 (Gross-Sampson, 2019) and Jamovi 1.2.0 (Navarro & Foxcroft, 2018) package programs. The graphics were drawn using the ggplot2 package in the 3.6.1 version of the open source R software.

2.4.2. Qualitative analysis

In the analysis of qualitative data, themes, subthemes, and categories were created from the coding based on the relevant literature, video recordings, and observations. The data were analyzed using the double cyclic coding technique, which is used in qualitative research (Miles et al., 2014). At the first cyclical level, researchers encoded some data independently from each other, and then, they compared the codes and calculated the percentage of compliance. To verify and remove themes and categories independently formed from subjective judgments, the researchers discussed the codes and then reached a consensus on the new themes/categories. At the second cyclical level, the same researchers continued to code the remaining parts of the data with the constant comparison technique (Corbin & Strauss, 2008). Then, in the analyses with the NVivo 8 tool, the codes and findings were interpreted and verbalized.

3. Results

3.1. Quantitative Results

Supplementary Table 1 presents the mean and standard deviations of the pretest and posttest scores of the boys and girls in the experimental and control groups. Although there is an increase in favor of the posttests in general, the girls' pretest (M = 8.59, SD = 3.17) and posttest (M = 14.97, SD = 5.48) averages are close to the boys' pretest (M = 8.87, SD = 3.17) and posttest (M = 14.94, SD = 5.70) averages (Supp.Table 1). According to descriptive statistics, the TEMA-3 pretest mean scores of the children in the experimental and control groups are close to each other; however, according to the posttests, there is a difference between the mean scores of the children in the experimental and control groups. A one-way ANOVA test was used to examine whether the difference between the pretest mean scores of the groups was significant (Supp.Table 2).

There is no significant difference between the children's TEMA-3 pretest scores in terms of the experimental (M = 8.92, SD = 3.18) and control (M = 8.46, SD = 3.14) groups (F(1, 623) = 3.245, $p > .05, \eta_p^2$ = 0.005). This situation reveals that the math skills of the children were similar before the experiment, when the children in the groups were supported by content-specific materials. Then, using a mixed-design ANOVA test, whether the change between the pretest and posttest scores of the children in the experimental and control groups showed a significant difference in terms of the groups was investigated.

In Table 3, because of the interaction of the group and measurement variables, the TEMA-3 scores of the children in different groups significantly changed from before to after the intervention. Thus, there is a statistically significant difference in favor of the experimental group between the TEMA-3 posttest mean scores of the children in the experimental (M = 18.03, SD = 5.55) and control groups (M = 11.77, SD = 3.34) (Supp.Figure 1). According to the partial eta-square effect size coefficient (η_p^2 = 0.49), the materials set up in the experimental groups' classes have a positive and significant effect on children's math skills.

A multilevel regression analysis was conducted to determine the variables that increase the posttest scores of the children in the experimental groups (Table 4). At children's level, the variables of gender, age, mother's education level, father's education level, children's interest in materials, peer interaction level were included in the model. For teachers, the variables of teachers' experience, time the MAWS stayed in the classroom, teachers' participation in the project, and teacher–child interaction levels were included in the model.

The intraclass correlation coefficient (ICC), calculated as σ^2 = 22.4 and τ_{00}=10.1 in the TEMA-3 posttest scores of the children in the experimental groups, reveals that approximately 31% of variation in children's TEMA-3 posttest scores is because of the differences between teachers. The ICC value obtained in this study is higher than the values reported in studies in the literature on education (5% < ICC < 25%) (Hedges & Hedberg, 2007; Peugh, 2010). This result shows that the difference in the TEMA-3 posttest scores of the experimental group children is caused by variables related to both children and teachers.

Because of including teacher and child-level variables in the model together, 68% of the total variance related to the TEMA-3 posttest scores of the experimental group children was explained (R^2 = .68). This result shows that the variables taken into account at the teacher and child levels together seriously affect the change in the TEMA-3 posttest scores of children. Considering the variables at the child level, children's gender (β = −0.38, p >.05) and age (β = 0.04, p >.05) were not significant predictors of their TEMA-3 posttest scores. Furthermore, while children's fathers' education level (β = −0.08, p > .05) was not a significant predictor, mothers' education level (β = 0.86, p <.05 .05) was a significant predictor of the TEMA-3 posttest scores. Therefore, the TEMA-3 posttest scores are higher for children whose mothers' education level is higher. Additionally, children's interactions with their friends (β = 3.56, p <.05 .001) and their levels of

Table 3
Mixed-design ANOVA result for the TEMA-3 test

	Sum of Squares	*df*	*Mean Square*	*F*	*p*	*ES*
Between-subjects						
Group (Experimental–control)	3521.83	1	3521.83	131.63	<0.001	.17
Error	16668.15	623	26.76			
Within-subjects						
Measurement (Pretest–Posttest)	12052.70	1	12052.70	2746.70	<0.001	.82
Group*Measurement interaction	2630.72	1	2630.72	599.52	<0.001	.49
Error	2733.76	623	4.39			
Total	37607.16	1249				

Note. ES = effect size

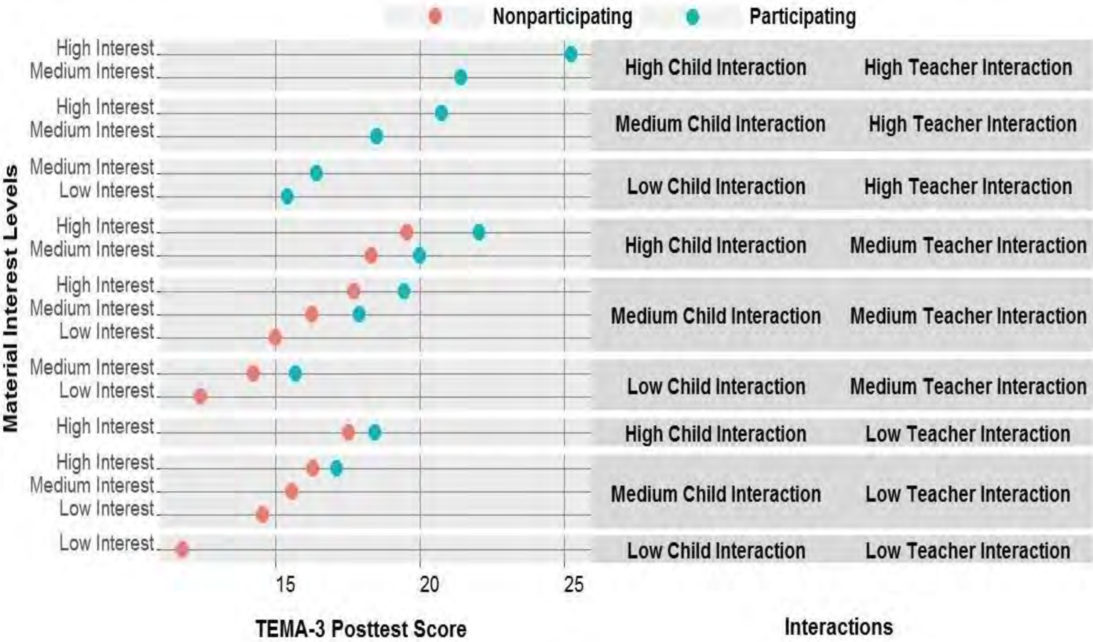
Table 4
Results of multilevel regression analysis

Level and Variable	*β(SE)*	*95% Confidence Interval* *Lower*	*Upper*	*t*	*p*
Intercept (γ_{00})	17.82(0.41)	17.02	18.63	43.27	<0.001
Student level					
Gender	−0.38(0.36)	−1.09	0.33	−1.06	.306
Age (month)	0.04(0.06)	−0.09	0.16	0.59	.567
Father's education level	−0.08(0.39)	−0.85	0.69	−0.20	.844
Mother's education level	0.86(0.30)	0.26	1.46	2.82	<0.05
Peer interaction level	3.56(0.71)	2.18	4.95	5.04	<0.001
Level of interest toward materials	1.90(0.44)	1.03	2.76	4.31	<0.001
Teacher level					
Teachers' experience (years)	0.22(0.07)	0.07	0.36	2.96	<0.05
In-class retention time of MAWS (hours)	0.00(0.00)	0.00	0.00	3.62	<0.01
Participation in the project	2.19(0.69)	−3.54	−0.83	−3.16	<0.05
Teacher–child interaction level	2.77(0.46)	1.87	3.67	6.06	<0.001

interest in the materials (β = 1.90, $p < .001$) are significant predictors of TEMA-3 posttest scores. Thus, children's interactions with their peers and the increase in their level of interest in the materials lead to an improvement in the TEMA-3 scores.

Considering the variables related to teachers (Table 4), teachers' experience (β = 0.22, $p < .05$) is a significant predictor of children's TEMA-3 scores. As teachers' experience increases, children's TEMA-3 scores also improve. Additionally, the duration that the MAWS stays in the classroom (β = 0.00, $p < .01$) significantly predicts the TEMA-3 scores. In other words, as the duration of the MAWS in the classroom increases, children's TEMA-3 scores also increase. Teachers' participation in the project (β = 2.19, $p < .05$) is another significant predictor variable. According to this result, children's TEMA-3 scores in the classrooms of the teachers participating in the project are significantly higher. Finally, teachers' level of interaction with children (β = 2.77, $p < .001$) is a significant predictor of children's TEMA-3 scores. Thus, an increase in teachers' level of interaction with children while using MAWS in the classroom environment also increases children's TEMA-3 scores. Figure 2 presents the interactions between the variables at the teacher and child levels that significantly predicted the TEMA-3 scores of the children in the experimental groups.

Figure 2
Relationships between the significant variables at the teacher and child levels



As shown in Figure 2, there is a significant relationship between peer interaction and teacher–child interaction, as well as interest in the materials and involvement of teachers in the project, which have been considered significant at the $p < .001$ level.. According to the chart, the posttest mean scores of the children in the classrooms of teachers who participated in the project and benefited from the training for the effective use of mathematics materials were higher than that of children in the classes of teachers who did not participate in the project. Further, teachers participating in the project interacted with the children at a higher level compared to others. This situation positively contributes to the TEMA-3 posttest mean scores of the children. However, the increase in the children's mathematical interaction level with each other seems to positively affect both the posttest mean scores and interest in materials. In other words, as peer interactions increased, children's interest in the materials increased, and accordingly, children's TEMA-3 posttest mean scores increased. Even in classrooms with low teacher–child interactions, high interactions between children increased both the interest in the materials and led to higher mean scores. According to the results of the research, as teacher–child and peer interaction levels increase, children's interest in the materials increases; this situation positively affects the TEMA-3 posttest mean scores.

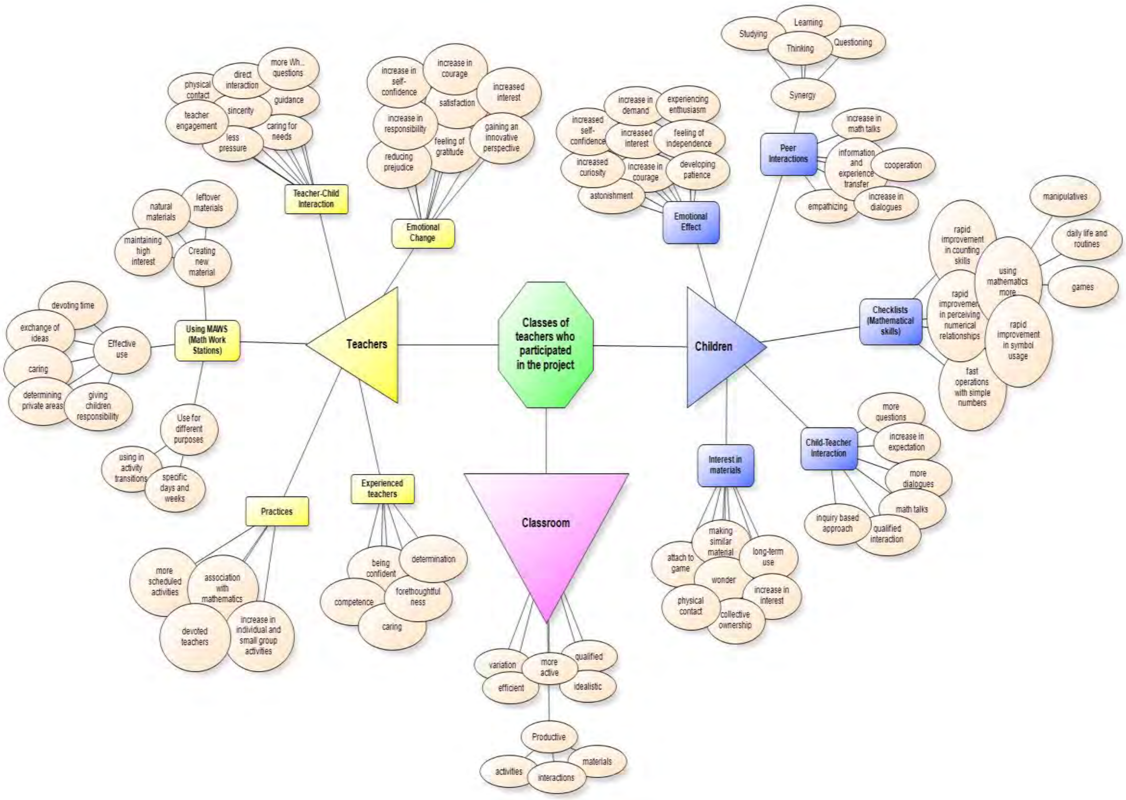
3.2. Qualitative Results

The qualitative data collected through video recordings, and observations were analyzed separately and examined comparatively. The intervention process caused a positive emotional change in the teachers participating in the project. They achieved personal development during the process. Teachers in the research process broke down their prejudices toward mathematics because of the experiences they gained in the project. Along with self-confidence and courage, they gained a new perspective toward mathematics. These teachers, who started to believe in the importance of two-way interaction, preferred the direct interaction method and established physical contact with children during the use of MAWS. This situation increased the sincerity of the interaction established by reducing pressure on children and facilitated the acceptance of teachers when children invited them to play cooperative games.

The teachers who viewed MAWS as a tool for children to structure their own learning believed that children should take responsibility and gave the necessary attention to the intervention by determining specific areas for the station in their classrooms. Teachers who were not satisfied with the available materials at the station tried putting together different materials with the children by using their creativity with the natural materials they gathered from the school surroundings and the materials left over from other activities. With such activities involving children, teachers provided children the necessary time to discover materials in the station and managed to maintain interest with small changes. Experienced teachers, who knew how to turn the changes in their classrooms into opportunities, showed determination to create a freer, more democratic, and idealistic climate in the classroom to benefit from the rich materials and interaction that MAWS provides for children without erring on the side of caution. Thus, MAWS, which were used even in different activity transitions, were used more effectively in the classrooms of confident, experienced teachers.

Figure 3

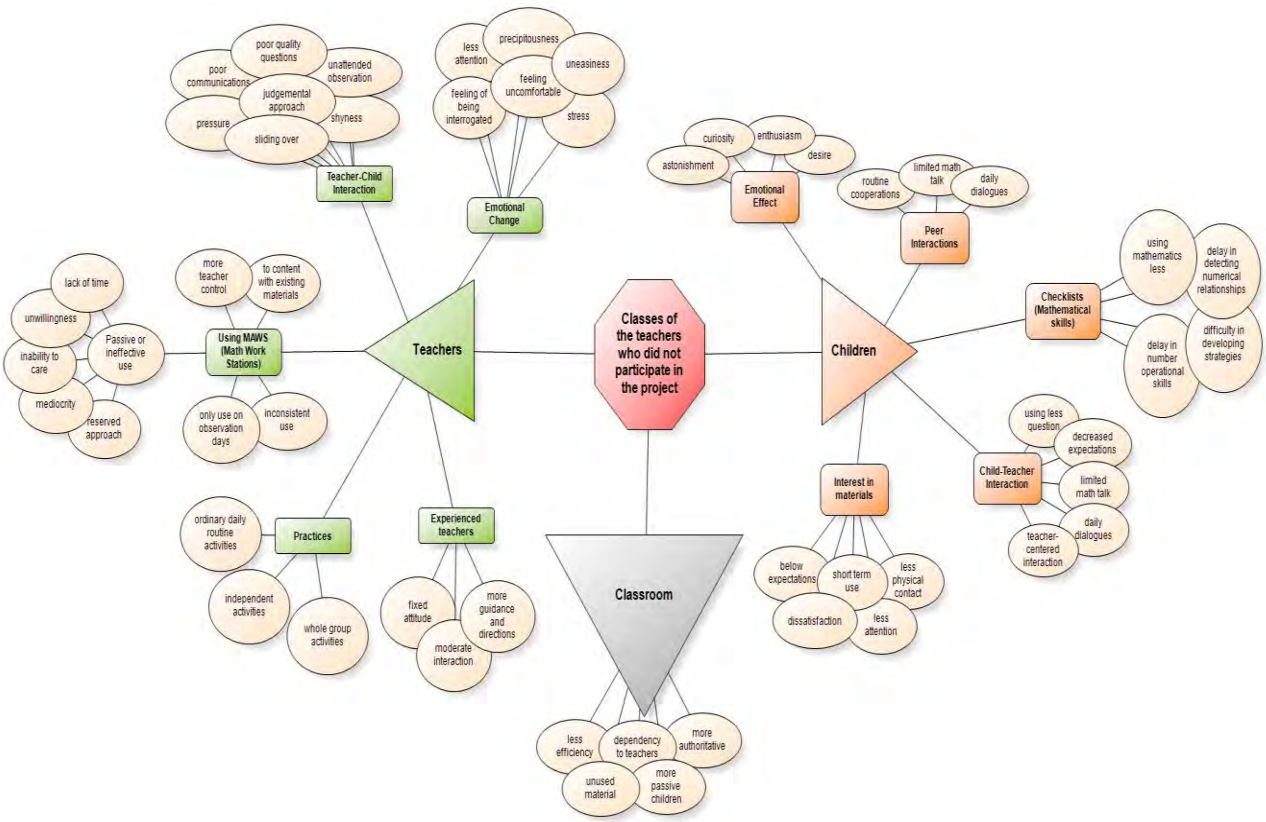
Observations and reflections in the classrooms of the teachers who participated in the project



Children of the experimental group who receive education in such classrooms were more curious, enthusiastic, brave, and excited with the support they received from their teachers. In these classes, where children interact more efficiently with their teachers and peers, more learning, thinking, and questioning ensues. With increasing interest in MAWS over time, the materials were used for a longer time and included in games. This situation, which increased mathematical dialogues, supported peer learning through assistance. In the skill checklists filled out during long-term observations for each child receiving education in classes in which the MAWS were set up, for children who had the chance to use mathematics more in their daily life and games, it was determined that counting, understanding numerical relationships, and processing skills with simple numbers improved faster than for other groups (Figure 3, for details see Supp. Table 5).

The situation was slightly different in the classrooms of teachers who did not participate in the project. In Figure 4, a detailed analysis of the video recordings from the classes of the experimental group teachers who did not participate in the training project (n = 4) and observations from the same classes was similarly conducted from the perspective of both teachers and children. The intervention process caused stress, anxiety, and tension for teachers who did not participate in the project. During the observations within the scope of this research, many teachers who were not interested in the research felt that they were being questioned by the researchers in the process and had lower-level interactions with the children.

Figure 4
Observations and reflections in the classrooms of the teachers who did not participate in the project



These teachers, who conducted the process in a dull, unwilling, passive manner, with superficial mathematics questions directed to the children, approached the intervention with reservations and preferred to follow the curriculum offered to them by the MoNE, except for the observation days when the researchers were present. Interestingly, the wrong attitudes of experienced teachers, who had a passive, authoritarian attitude despite having rich materials, caused the children to be exposed to inefficient, unrelated large group activities during the intervention. Children who showed astonishment, curiosity, and desire toward materials in the first days when the MAWS was set up in their classrooms lost their enthusiasm as the process continued. In the classrooms of the inexperienced teachers who provided insufficient information to children about the materials at the station and their usage, children had a shorter attention span toward the materials; therefore, mathematical dialogues were limited. Vertical communication was preferred in these classes where teacher control was intense, and teachers received fewer questions. Children whose expectations decreased over time used limited math talk in their dialogues with teachers. In the skill checklists filled out for each child in the classrooms of the experimental group teachers who did not participate in the project, for children who had to use mathematics less in their daily lives and games compared to the previous group, it was understood that counting, understanding numerical relationships, and processing skills with simple numbers showed a more delayed development. Thus, children who receive education in such classes have difficulty in developing different mathematical strategies (Figure 4, for details see Supp. Table 6).

4. Discussion

In recent years, interest in identifying ways to improve children's mathematical skills in ECE classes has increased. While some studies have used correlational methods to investigate the relationships between teachers' classroom strategies and the development of children's math skills (Mackintosh & Rowe, 2021; Trawick-Smith et al., 2016), other studies have used experimental methods for this purpose (Ramani et al., 2012; Vogt et al., 2018). The current study, with the inclusion of activities based on the use of context-specific materials, investigated the effect of an intervention program specifically aimed at training teachers to serve as responsive partners that conduct quality mathematics education with children to hone their mathematical skills. In doing so, the study used correlational and experimental methods to examine the process in detail according to changing teacher and child characteristics.

The results showed that mathematical activities that increase the quality of the educational environment and support teacher–child and peer interaction can lead to improvements in children's mathematical learning, even if they have different family backgrounds. In this study, mathematics materials developed using simple equipment were transformed into purposeful toys in the classroom with the help of the MAWS and included in the education process by teachers at certain time intervals. The findings indicate that the mathematical skills of children educated in classrooms with enriched materials increased. However, notably, this positive effect is not only because of materials because the use of materials is only effective when they are used to encourage children to think and make connections between objects and abstract mathematical ideas. The literature indicates that early mathematics achievements are associated with children's demographic characteristics, their teaching process elements and quality, and social environment (Lee & Ginsburg, 2009; Ryoo et al., 2018). In this study, the age and gender variables at the child level were not significant predictors of the scores obtained. Although some previous studies show that the age variable significantly predicts children's math skills (Gurgah Ogul & Aktas Arnas, 2020), it is likely that this was because of participants' demographic variation. Most kindergartens in Turkey do not provide education in mixed age-group classes. Instead, children with similar chronological ages in months are included in the same class, and children are expected to have similar developmental characteristics. Therefore, the ages of the children participating in the study are close to each other, and the duration of the intervention may not be long enough to reveal the effect of age. Additionally, contrary to studies that consider the gender variable as a factor affecting children's mathematics achievement (Chang et al., 2011), the current study reveals that when children are presented with similar social and physical conditions in a desired manner, mathematics success may increase for both genders. Therefore, the quality of the learning process is more likely to contribute to children's early math skills than their biological aspects.

Additionally, mothers' education levels predicted the mathematics achievement scores of children rather than that of fathers; therefore, children whose mothers had a higher education level got higher scores on the test. Although the reason for the emergence of this finding is related to the perception that mothers pay more attention to their children than fathers (Del Río et al., 2017), studies on family involvement that support the current study show that before children enter a formal school environment, they can acquire experiential knowledge about mathematics at home, mostly depending on the educational status of their mothers (Gurgah Ogul, & Aktas Arnas, 2020). For example, Skwarchuk et al. (2014), in their study with 40 mother–child pairs, revealed that more educated mothers can create situations at home where their children can learn more mathematics. Similarly, home numeracy environments created based on parents' education level are a permanent and important factor in early math skills development (i.e., understanding numerical relationships and arithmetic skills) (Susperreguy et al., 2020). In light of these studies, the mathematical skills and experiences that young children bring to school may differ, but their causes are more likely to be related to different past experiences (Lee & Ginsburg, 2009). Therefore, teachers should be aware of and sensitive to these differences. The fact that all children, regardless of their backgrounds and previous experiences, can learn mathematics should never be overlooked. A good mathematics curriculum and instruction can make up for shortages in children's early mathematics knowledge (Sophian, 2004). This study's findings reflect teachers' attitudes toward mathematics education and the differences in their strategies toward children. The fact that approximately 31% of the variability in posttest scores was due to teachers explains these differences.

As expected, the integration of materials into activities over different durations changed the teaching processes and strategies that teachers use to a certain extent. The inclusion of MAWS in classrooms has encouraged teachers to effectively use materials, participate in games, and prefer an inquiry approach while facilitating children's learning and sharing with games. In regard to other teachers who benefited from the project training and who could effectively integrate MAWS into the teaching process, the researchers observed that children engage in more high-level mathematical interactions to develop their thinking skills, incorporate these skills in discussions, brainstorm problems encountered, and integrate new concepts with real examples (Karademir & Akman, 2019). This result shows that the project training contributed to the teachers' classroom mathematics activities. This supports previous works that link teachers' roles as facilitators in the process and increases in peer involvement and interactions (Mackintosh & Rowe, 2021). Additionally, the findings showing that there is a positive relationship between the amount of time the MAWS stay in the classroom and mathematical skills contribute to the studies that establish a meaningful linear relationship between the mathematics achievements of children with the time spent on the subject (Ginsburg et al., 2008). Consecutive qualitative analysis revealed that teachers provided support corresponding to the needs of each child regarding the materials by using mathematical language. Because of this situation, greater improvements were observed in the mathematics scores of the children in these groups. These findings are consistent with studies and reports that consider good quality interactions between teachers and children a prerequisite for learning (Burchinal et al., 2015) and suggest that there are causal relationships between mathematical language and math skills (NAEYC/NCTM, 2010; Uscianowski et al., 2020). The intervention did not change the time that children spent in the classroom or the number of teachers. Rather, in addition to the current curriculum, teachers' interactions with children were more open and comprehensive. It supported skill development by providing tools, strategies, materials, and increasing children's use of mathematical language. Therefore, teachers' assuming the widely accepted scaffolding role (Vygotsky 1978) during the intervention and using the mathematical language with a more questioning-based perspective by focusing on mathematics activities may have increased children's knowledge of mathematical concepts and positively affected their mathematical development (Klibanoff et al., 2006). Similar to previous research results, the fact that teachers include techniques that facilitate questioning in the classroom allows children to engage in conceptually challenging discussions while positively affecting the classroom atmosphere and facilitating children's participation in the process of creating and sharing knowledge (Karademir & Akman, 2021).

This study has shown that fun mathematics activities presented in developmentally appropriate ways contribute to teacher–child interactions and increase the likelihood of children engaging as more active and responsible participants in interactions. Based on these observations, teachers' purposeful gamified interactions with children rather than daily compulsory dialogues increase the possibility of children switching to independent play without the need for adult support. This situation, in line with the results of Trawick-Smith and Dziurgot (2011) and Bodrova and Leong (2006), shows that when teachers shape their interactions according to children's needs, children can easily manage complex, social, and autonomous games in the future. These findings show that good quality teacher–child interactions, in which the amount of support is adjusted using responsive strategies, are associated with higher social-emotional and cognitive achievements, thus contributing to recent studies (Bleses et al., 2020; Slot, 2018). It also draws attention to teachers' efforts to create developmentally appropriate social and physical environments and hints to the importance of teachers' experience for the learning process. This study found that experienced teachers, in comparison to their colleagues who just started teaching, use teaching strategies that increase children's interest more effectively without feeling anxious about the curriculum, parental pressure, stress, and lack of trust. Although there are studies in the literature stating that teacher characteristics do not affect children's mathematical development as much as their teaching processes (Ryoo, et al., 2018), this situation contains contradictions in itself. Previous studies focusing on teachers' educational status and experiences (Ginsburg et al., 2008; Hu et al., 2017) have emphasized that these features can be effective variables in determining teaching strategies and deciding how activities will be performed. Compared to other classes, the findings obtained from the experienced teachers' classes where the intervention was performed show that by giving children the opportunity to interact more with materials and peers, rich, long-term, provocative contexts were created. Additionally, the six teachers who participated in the project training were found to be more successful in classroom organization and time management than those who did not (Figure 3). It was determined that these teachers mostly participated in activities directly and tried making use of teachable moments (i.e., opportunity training). These findings, which show why professional experience and involvement in the project may be related to children's mathematics development, enrich the research that suggests that both elements are critical for good quality early mathematics teaching (Clements & Sarama, 2008; Li, 2021; Pianta et al., 2009). Li et al.'s (2020) study states that young teachers at the beginning of their careers who have MAWS set up in their class have a higher ability to engage children in interactions. In contrast, this study found that young teachers were unable to fully perform indirect guidance for children but rather used direct instructions (e.g., worksheets, exercises, and desk activities) and tried conveying academic content by focusing on numbers and children's knowledge of shapes. This supports the results of recent studies that although gamified teaching models should be used frequently in ECE, these are not employed because of curriculum concerns, teacher training and qualifications, and pressures caused by parental attitudes and beliefs (Bubikova-Moan et al., 2019; Karademir et al., 2020). Because ECE has become more academics-focused and teacher-centered activities have increased (Hesterman, 2018), considering the risk of decreasing children's learning (by themselves) through games (Miller & Almon, 2009), these findings confirm Ginsburg et al.'s (2008) concern that teachers may put less emphasis on other mathematical skills by overusing activities for the same goals. Unfortunately, considering the results obtained from the recent studies and reports on early mathematics education, there is not enough emphasis on mathematics in ECE classes, and the need for teachers' training on how and what to teach is still valid (Bubikova-Moan et al., 2019; Li, 2021).

The current intervention gave teachers the chance to develop experiences by participating in games, questioning together, and taking on an effective guidance role (Pyle & DeLuca, 2017), emphasizing gradual adult support (scaffolding). Further, it presented children with the opportunity to discover new ways of interacting with purposeful materials in games and to manage their own learning with their peers within established game contexts (Weisberg et al., 2013). This way, instead of reducing children's playtime to directly teach predetermined mathematical concepts and knowledge, the teachers in the process had the opportunity to rediscover the roles of games, interactions, and materials in learning in the context of game-based teaching. However, as expected, classroom practices differed depending on teachers' beliefs regarding the intervention and the current system's conditions. The teachers who benefited from the project training (n = 6) tried applying more individual or small group math activities, rather than large group activities, and used the language of mathematics effectively, compared to those who did not. Thus, children who receive more indirect support could share more frequently with their peers (Figure 3). With this intervention, in which purposeful game environments could be created suitably for small group activities, depending on the developing peer collaboration and guidance, it can also be said that children's interest in the materials increased (Figure 2). These findings indicate that in addition to the facilitative roles of adults (Ramani et al., 2012), peer interactions can also play a key role in the realization of mathematical learning. When considered together, in line with the literature, these findings show that, informal learning integrated with social interactions (Mackintosh & Rowe, 2021) can play an important role in developing basic mathematical concepts for children who may need such opportunities. Additionally, the experimental group teachers who could not participate in the project (n = 4) could not benefit from the MAWS effectively in spite of the informative booklets (Figure 4). Observations in these classrooms showed that teaching continued with academically focused curricula, and teacher–child interactions could not go above the medium level. These beliefs may be related to the emotions arising from teachers' own negative experiences with mathematics that Benz (2012) noted. In these classrooms, where the process was observed to be less efficient, based on checklists, it was found that children use mathematics less in daily activities and games and experience delays in perceiving numerical relationships and developing number-processing skills. These findings, in line with recent research regarding the developmental needs of children, indicate that appropriate and adaptable mathematical learning opportunities that take instructional differentiation into account are still not fully used by teachers (Bubikova-Moan et al., 2019; Vogt et al., 2018). The other six teachers admitted that their takeaways from the project in which they participated motivated them and made them develop facilitating alternative perspectives. These teachers considered the approach involving the use of MAWS as a tool for ECE that could go beyond direct instruction and support the learning of academic skills. Because children in the classrooms of these teachers were more intertwined with mathematical experiences than others, it was determined through checklists that there were faster improvements in counting, the symbolic use of numbers, understanding numerical relationships, and simple operation skills. Thus, using the experimental group teachers' different perspectives and practices with regard to the intervention, this study highlights the potential need for more guidance and practical knowledge for ECE teachers on gamified pedagogical approaches beyond the use of MAWS.

5. Conclusion

This game-based intervention to improve the mathematics teaching process in ECE classrooms was entirely child-centered. It emphasizes the significance of integrating academic concepts into the teaching process in an engaging and developmentally appropriate way, expanding children's interests, and using game-based strategies that match children's abilities. The intervention also focused on children and their developmental needs and teacher training in classrooms, as well as highlighting the mathematical focus. The intervention provides teachers the opportunity to teach with sustainable, gamified, engaging materials integrated into the classroom, providing necessary guidance for children to extend their learning. For this reason, starting from the context of Turkey, this study has implications for the international field on how ECE teachers can successfully expand the teaching strategies they use within the scope of mathematics education. Further, it discusses how to professionally develop instructional applications that encourage interaction during mathematics activities. This study also shows how the quantity, number, and simple operation skills of children changed by using MAWS, which bring an innovative approach to early mathematics education. The results highlight that improving physical conditions alone is not enough to meet the individual needs of children and develop their academic skills. This study reminds educators once again that no matter how good the learning materials, children's educational potential can only be realized with good teaching and learning support. In this approach, teachers try to understand children better with their content knowledge, structure their learning situations, ask questions, show strategies to solve mathematical problems, and encourage mathematical discussions (Wullschleger & Stebler, 2016). Therefore, the game-based approach developed proposes guided games that deal with the social and physical environment together.

During the process, behaviors of the teachers participating in the research had a great variation, and the differences in their experiences affected the usage of MAWS. In spite of the improvement in environmental conditions, some of the teachers (non-participating teachers in the project, n = 4) were unfortunately unaware of children's mathematical competences, were unable to establish appropriate interactions, and failed to provide students with appropriate learning experiences (Trawick- Smith et al., 2016). This result underlines the need to review teacher education programs in terms of mathematics education. Li’s (2020) study, with 100 teachers from different ethnic backgrounds, shows that ECE teachers still cannot use even basic mathematical knowledge correctly and that teachers need comprehensive training. The encouraging results obtained in the experimental context from the classrooms of the teachers who participated in the project indicate that teacher training is necessary and that purposeful game materials that improve the quality of the social-physical environment can be integrated into the existing curriculum. The developments and positive changes observed in the six teachers who participated in the project contain important clues about the necessity of pre-service and in-service trainings.

It is gratifying to see that teachers put the children into positions in which they were responsible for their own learning in classrooms where the intervention was conducted effectively. While creating positive emotional effects (e.g., courage, self-confidence, curiosity, and interest) in children, guided games in which children are active regardless of their demographic characteristics supported children’s learning by helping each other through cooperation. Further, sometimes teachers can use coincidences, improvisation, and teachable moments to promote learning. To this end, it may be necessary to participate in activities directly as a teacher (Hackett et al., 2018). Although there are strong traditions in ECE pedagogy, this study confirmed that children whose teachers are trained in techniques including the scaffolding approach have more frequent, long-term, and good quality environmental interactions. Based on daily experience observation records, purposeful and material-rich approaches for early mathematics education that support social relationships certainly can be innovative for children and practitioners. Finally, the MAWS approach, a pedagogical case example that offers guidance and planning for teaching children about certain mathematical content, can help characterize the basic aspects of the work at hand while providing a more productive environment for mathematics learning, especially for children who are from a disadvantaged background.

6. Limitations and Future Directions

Although the study’s results are convincing, they should be considered together with the limitations of the study. This study’s data are based on the experiences of preschool teachers and children in Turkey. Therefore, the results may not directly reflect teacher practices in ECE institutions in different countries. The qualitative in-depth and observational data in this study are among the first examples of teaching mathematical applications using MAWS in classrooms, yet there is a requirement for additional data to make definite claims. Given the increasing emphasis on ECE mathematics and game-based pedagogies that incorporate quality interactions, future research should continue to examine the relationship between teachers' use of materials and the effects of game-based teaching processes on children in relation to the activities they conduct. Additionally, teachers need emotional and pedagogical support the designing and carrying out of mathematical activities that are suitable for game pedagogies that involve purposeful material use. Therefore, future researchers should provide different experimentally supported activities to monitor and measure gamified mathematics education and learning styles that can alter teachers' negative perceptions of mathematics. The relationship between teacher–child interactions and evaluations of a wider range of math skills should be examined. Specifically, other evaluation dimensions, such as geometry, measurement, and problem solving, that are not fully addressed in TEMA-3 should be used. Future work should also examine specific situations between various gamified teacher–child interactions, the development of particular game skills, and mathematics learning. This will allow a better understanding of the game elements that are developed through teacher interactions and are most relevant to mathematical thinking. Finally, more research is needed to support teachers' professional development to increase the competence of teachers who strive to integrate activities in which meaningful mathematical learning happens at the ECE level because early mathematics education is crucial for long-term success and quality of life. Innovative and evidence-based approaches that encourage children to learn mathematics by connecting their strengths and daily activities are essential to acknowledge the educational rights of all children.

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