

IMPACT OF EARLY NUMERACY TRAINING ON KINDERGARTENERS FROM MIDDLE-INCOME FAMILIES

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ABSTRACT

The aim of this work was to evaluate the effectiveness of a supplemental early numeracy skills training program for typically developing middle-income pre-school and kindergarten children (age 4-5) enrolled in a standard educational program. Three conditions were compared: cooperative learning training; individual learning training; and no training (control group). Results showed that the scores of all groups increased significantly between pre-test and post-test, but no significant differences were found between the children exposed to additional training and the control group. This finding suggests that an intervention may not be more effective than good standard schooling with such young children, and that there is a need for further investigation in this area. In a follow-up analysis, the hypothesis that the effectiveness of an early math intervention is more apparent in low-ability children was tested. For children with low early math ability, performance in terms of early numerical competence before and after the intervention was compared to a control group of equally low early math ability kindergarteners. Results showed a significant difference between pre- and post-test in both the experimental and control groups, but the training group showed higher achievement with respect to the control group. This finding suggests that it may be important to carry out interventions on children with low-ability in early math competence, even in a middle-income social context.

KEYWORDS

Early numeracy skills, training, cooperative learning, low early math ability preschoolers

1. INTRODUCTION

Recently, an increasing number of researchers have been concerned with children's early number competence and its relation to mathematics achievement. Numerical competence is a key element both in education and in everyday life, and early math skills training from the preschool level may be a preventive factor for future difficulties in learning mathematics (Geary et al., 2013). Several intervention programs have proven effective in enhancing early numeracy skills at a preschool level, with a focus on abilities such as counting, recognizing and writing numbers, one to one correspondence, comparison of numbers and dots, and understanding of numbers and quantities (e.g., Arnold et al., 2002; Ramani & Siegler, 2008). Most of the studies have been conducted in schools attended by low-income children. For instance, Ramani and Siegler (2011) compared middle-income with low-income children of different ages: the results showed that both children from low and middle-income families benefited from an early math intervention, although children from low-income backgrounds took more advantage of the intervention and learned more than less needy children.

Few studies have investigated the effects of early math skills training in children from middle-income families. In one study conducted in Italy, Passolunghi and Costa (2014) found that five year old mainstream children could benefit from domain-specific early math training.

Regarding math training, a fundamental issue is how to give effective instructions to introduce preschool and kindergarten children to numeric and quantitative concepts. One powerful method to improve learning in children is cooperative learning. Cooperative learning (CL) involves the use of small groups in which students interact with each other and work together to achieve shared goals. Although its effectiveness is well-attested in literature (Johnson et al., 2008), CL has received little consideration for children younger

than six (Wiegel, 1998). Indeed, Vermette et al. (2004) underlined how the evidence about CL comes from classrooms from the third grade and “up”. One of the rare studies, in which an experience of CL math training with kindergarten children is described, was conducted by Artut (2009). In this study, the effects of CL on early math ability were investigated by comparing a CL training group to a control group in which other forms of training were implemented. A significant improvement was noted in mathematical abilities in the CL group, but the work does not exactly specify the children’s ages, nor does it provide details about the specific cooperative learning activities.

Our study had three main aims: to explore the effectiveness of a supplemental (i.e., in addition to the standard school curriculum) intervention in early math competence in typically developing children (aged 4-5) from middle-income families and to explore which kind of math training is the most efficient for kindergarteners, thus contributing to the discussion about the efficacy of cooperative learning in children younger than six years of age. We also wondered whether the efficacy of an early math supplemental intervention in middle-income children is more apparent in children with low early math abilities.

To achieve these aims, we assigned a sample of typically developing kindergartener (4-5 years of age) to three experimental groups: one group was exposed to structured cooperative learning early math training; a second group was assigned to individual learning early math training; and the third group was assigned to a control group involved in drawing and coloring activities. All children underwent kindergarten education in mathematics during the time of the intervention, following the standard early math curriculum established by the Italian Ministry of Instruction (Annali pubblica istruzione, 2012). Children’s performances before and after math training were compared. Then, to test the hypothesis that the efficacy of an additional intervention is stronger in children with low early math abilities, in a follow-up analysis, we compared a subsample of low ability children’s performance before and after the training with the performance of an equally low ability control group.

According to studies investigating the importance of early numeracy skills training in mainstream kindergarten children (Passolunghi & Costa, 2014), we expected to find an improvement in children’s early math skills after a domain specific training supplemental to the standard math curriculum. Based on the literature related to children from low-income families, we expected to find the training to be especially beneficial in low-ability children (e.g. Ramani, & Siegler, 2008).

Regarding the efficacy of different kind of interventions, we decided to compare structured cooperative learning training with individual training. As discussed above, there is very little research on the effectiveness of cooperative learning for children younger than six years of age; thus, it is quite difficult to make an exact prediction regarding its effectiveness on children as young as those from our sample. According to data coming from primary and secondary schools (Johnson et al., 2008), we expected a better outcome from cooperative learning training as compared to individual training.

2. METHOD

2.1 Participants

Forty-three typically developing 4 and 5 year old Italian children (19 males and 24 females) were recruited from a public kindergarten school in the town of Cagliari (Italy). Children with significant developmental delays (as identified by local educational and health services) were excluded. Both the school and the children’s parents agreed to let the students take part in the research study, signing informed consent forms. The participants involved in the study came from two different classes (sections A and B), in which the same two teachers evenly rotated. The participants’ average age was 56.55 months (SD = 6.29), with a range of 47-66 months. The socioeconomic status of the sample was measured by the Family Affluence Scale (FAS) (Boyce et al., 2006) and was classified as middle-class (mean = 6.5, SD = 1.1, scale range 0-9). Children were assigned to one of the following conditions: cooperative learning (CL) training group (15 children, 6 males); individual learning (IL) training group (14 children, 7 males); and control group (14 children, 6 males). The three groups were balanced for the following variables: initial early math ability measured through a standardized early math test, the BIN 4-6 (Molin et al., 2007); gender; age; IQ score; and school class.

2.2 Procedure

The study was divided into four phases:

1. Familiarization with students and teachers: three researchers (the first author and two trained psychologists) were in the classroom during normal class activities for two weeks, interacting and playing with the children.
2. Pre-training assessment. The Italian standardization of Raven's Coloured Progressive Matrices in the Italian standardization (CPM, Belacchi et al., 2008) was used to assess children's IQ so as not to include in the study children with low levels of intelligence. The BIN 4-6 (Molin et al., 2007), an early math abilities standardized test, was used to develop a baseline of early numeracy skills.
3. The training phase. While children assigned to cooperative and individual learning were involved in the supplemental early math training with two researchers (in two different classrooms), children assigned to the control groups participated for the same amount of time in drawing activities led by the third researcher (in a third classroom). The three researchers rotated evenly between the three activities. The two experimental groups were exposed to the same learning materials (see below for details). Each math activity comprised two steps: a manipulation or movement game followed by a paper-and-pencil consolidation task. The aim of each meeting was the enhancement of different aspects of early numerical competence (Lucangeli et al., 2003). The only difference between the two groups was the way the lesson was implemented: cooperative versus individual. The training was divided into 12 weekly meetings. The individual training sessions lasted about 30-40 minutes. The CL activities, due to the longer instruction time, lasted for about an hour.
4. Post-training assessment. The children's early numerical competence was retested with the BIN 4-6 (Molin et al., 2007) to assess the effects of the training.

2.3 Training Materials

For both training activities (CL and IL), we used several structured learning materials, such as short stories, games, and practical activities about numbers, specifically developed for early math training for children from three to six years of age (Lucangeli et al., 2003) and for consolidation interventions (Judica et al., 2010). Activities were conducted that focused on the following areas: the lexical area (distinction between numerical symbols and letters, telling stories with numerical elements, association symbol/name-number, writing Arabic numerals from number 1 to number 5); the semantic area (connect the number-words to their correspondent numerical quantities; comparing Arabic numerals e.g., "Tell me which is more, 2 or 4?"); the counting area (numbers sequence, count forward, count backwards), and operations in the pre-syntactic area (comparing and ordering quantities of up to five elements).

2.4 Cooperative Learning Activities

The learning together approach (Johnson et al., 2008) was followed to complete the CL training. Students were asked to work cooperatively in pairs. Different pairs were formed for each different session, so students had the chance to work with different partners, and heterogeneous pairs in terms of skill levels were structured (Johnson et al., 2008). Children were instructed to perform the following steps to cooperate effectively: (1) listen to the different questions and formulate the answer individually; (2) share the answer by whispering to the other group member; (3) try to reach an agreement with the other group member; and (4) be ready to answer if asked.

Students whose answer was required had to share it with the class. A practical demonstration of this procedure was performed by the instructor to provide the children with a concrete behavioral model. Positive goal interdependence and positive identity interdependence were established among group members.

At the end of each activity, the scores of each pair were shared and commented by the teachers with all pairs (final evaluation) and the students were encouraged to celebrate other students for the successes obtained (Johnson et al., 2008).

2.5 Individual Learning Activities

Children in IL conditions were asked to sit on small chairs that formed a circle, while the researcher explained the instructions for the math activities. Each child then had to carry out the tasks independently without help from his/her classmates. Later, the children sat around a table, and each child received a card for a paper-and-pencil consolidation task that had to be completed independently. During all the activities, the researcher was present to offer help, support, and motivation to each child while he/she worked.

2.6 Drawing Activities

Control group children were asked to freely play with building blocks and other toys and then to make a drawing of their activity under the supervision of the third researcher.

3. RESULTS

To compare the three groups (cooperative learning training, individual learning training, and control groups), three Kruskal-Wallis tests were used to determine possible pre-training, IQ, and age effects between the three groups ($p > .05$). Three Wilcoxon tests were used to determine gender effect ($p > .05$). Non-parametric statistics were used due to the small sample size and the difficulty of checking the assumption of normality of data.

The first question of this study was related to whether additional training in early numeracy skills is effective in enhancing early numerical competence in kindergarten children from middle-income families. A Wilcoxon test for paired sample was used to compare the CL group performance in early numeracy competence (dependent variable: BIN 4-6 z-score) in the pre- and post-training evaluation. The test results showed a significant difference ($V = 0$, $p = .002$, $|r| = .88$). A second Wilcoxon test for paired sample was used to compare pre- and post-training early numeracy competence (BIN 4-6 z-score) in the IL group; the results showed a significant difference ($V = 0$, $p = .003$, $|r| = .88$). The third Wilcoxon test for paired sample was used to compare pre- and post-training early numeracy competence performance (BIN 4-6 z-score) of the control group. The results showed a significant difference between pre-test and post-test also in the control group ($V = 0$, $p = .006$, $|r| = .83$). Descriptive statistics (median, IQR, CI, V, p-value, and effect size- r) of BIN z-score are reported in Table 1.

The Wilcoxon test results showed that early math abilities grew significantly in all the groups: CL training, IL training, and control group.

Table 1. Pre-test and post-test z-scores on test BIN 4-6 in the three groups, V, p values with Bonferroni correction and effect size $|r|$

Group	pre-test			post-test			V	p	$ r $
	Median	IQR	95% CI	Median	IQR	95% CI			
Cooperative Learning Training (n=15)	-0.48	1.28	[-1.63, 0.57]	0.50	0.44	[-0.29, 1.44]	0	.002**	0.88
Individual Training (n=14)	-0.10	0.79	[-0.84, 0.82]	0.65	0.62	[0.1, 1.2]	0	.003**	0.88
Control Group (n=14)	-0.44	0.49	[-0.96, 0.41]	0.28	0.69	[-0.29, 1.08]	3	.006**	0.83

Note. N = 43; * $p < .05$; ** $p < .01$; CI = confidence interval; r = effect size

To determine if one group had improved more than the others, we created a BIN test improvement score (BIN-IS) by calculating the differences between total BIN z-scores at pre-test and total BIN z-scores at post-test, and using these as dependent variables in a Kruskal-Wallis test. The results did not reveal significant differences between the three experimental groups ($\chi^2(2) = 1.79$, $p = .41$). By observing median and IQR of BIN-IS in the three groups, it is evident that children involved in the CL training (median = 0.93; IQR = 0.40; 95% CI [0.18, 1.96]) seemed to achieve higher than children in the individual training group

(median = 0.63; IQR = 0.53; 95% CI [0.17, 1.4]) and the control group (median = 0.71; IQR = 0.57; 95% CI [-0.06, 1.6]), although the difference was not statistically significant.

Our findings showed that all children, control group included, significantly improved their performance in early math competence from the first to the second assessment (12 weeks' time lag) without a significant difference between the three situations. The improvement demonstrated in the three groups is not dependent on age because, in statistical analysis, we used the z-scores of the standardized early math ability BIN 4-6 test to control age effects.

One of our aims was to verify if the efficacy of an early math domain specific intervention was more strongly apparent on low-ability children. To test the hypothesis that early math low-ability children may benefit from the training more than high and medium ability ones, we carried on a further analysis on a sub-group of participants. We extracted from the general sample the children who had scored at least a half standard deviation below the average normative score in the pre-test BIN 4-6. The obtained sample of 25 participants (11 males and 14 females) was divided into two groups: a training group of 14 participants (7 males and 7 females, selected from both the cooperative and individual training groups) and a control group of 11 participants (4 males and 7 female) selected from the control group. The average age participant's age was 54.4 months (SD = 6.6 months). The choice to use as a cut-off half a standard deviation below the mean was motivated by the necessity to select a sample of children with low early math ability but still with typical development: considering children with a score below one standard deviation (i.e., those included in the "request for attention" zone according to the BIN 4-6 manual), would have potentially led to an atypical development sample.

To analyze the data from the sample of 25 low-ability children, Wilcoxon tests were used. The use of non-parametric statistics was due to the small sample size and to the difficulty to check for the assumption of normality of data. Different Kruskal-Wallis and Wilcoxon tests were performed to ensure that the two groups were balanced for BIN z-scores, IQ, age and gender. No significant differences were found ($p > .05$).

A first Wilcoxon test for paired sample was used to compare the performance in early numeracy competence (BIN 4-6 z-score) in pre- and post-test in the training group and results showed significant differences ($V = 0$, $p = .002$, $|r| = .85$). A second Wilcoxon test for paired sample was used to compare the performance in early numeracy competence (BIN 4-6 z-score) in the pre- and post-test in the control group, and results showed a significant difference ($V = 1$, $p = .005$, $|r| = .76$). Descriptive statistics (median, IQR, CI, V, p-value, and effect size-r) of the BIN z-score are reported in Table 2.

The results showed that both groups enhanced their early math ability from pre-test to post-test time. To test if the training group improved more compared with the control one, the same BIN-IS score used in the previous analysis was used as dependent variable, and a Wilcoxon test was carried out to compare the two groups. The results showed a significant difference between the two groups ($W = 114$, $p = .04$; $|r| = .40$). By observing the median and IQR of BIN-IS in the two groups, it is evident that children in the training condition (median = 0.96; IQR = 0.53; 95% CI [0.65, 1.98]) achieved higher improvement when compared with the control group (median = 0.69; IQR = 0.47; 95% CI [-0.07, 1.66]).

Two Wilcoxon Tests were also performed to test for a gender difference in children's BIN-IS. Results did not show significant differences between males and females in the two experimental groups ($p > .05$).

Table 2. Low-ability children pre-test and post-test Z scores on test BIN 4-6, V, p values with Bonferroni correction and effect size (r)

Group	pre-test			post-test			V	P	r
	Median	IQR	95% CI	Median	IQR	95% CI			
Training group (n=14)	-0.83	0.35	[-1.65, -0.39]	0.38	0.40	[-0.30, 0.63]	0	.002**	0.85
Control group (n=11)	-0.79	0.52	[-1.23, -0.43]	0.09	0.84	[-1.21, 0.91]	1	.005**	0.76

Note. N = 25; * $p < .05$; ** $p < .01$; CI = confidence interval; r = effect size

4. GENERAL DISCUSSION AND CONCLUSION

This study involved 43 middle-income, typically developing children (aged 4-5) attending kindergarten in a public school in Italy. The main aim of our study was related to whether a supplement to the standard curriculum intervention in early numeracy skills would improve early math performance by confronting children exposed to two different interventions (cooperative learning and individual learning) and a control group. We wondered also whether early math training could be useful for children starting with a low level of numerical and quantity concepts knowledge.

First, the numerical skills baseline of participants was measured. Afterwards, training in early numerical competence was implemented in a cooperative learning training group and in an individual training one, while a balanced control group was involved in drawing activities. Finally, the children's numerical skills were measured again to evaluate the effectiveness of the training.

Regarding the first aim of this study, our findings showed that all children, control group included, significantly improved their performance in early math competence from the first to the second assessment. Thus, it appears that an additional intervention was not any more effective than the standard school activity: our data showed that neither CL nor individual training was effective in terms of significantly improving children's math abilities beyond the level reached through standard teaching. The results of our study are not in line with the previous literature on the effectiveness of early math training programs (e.g., Clements, 2007), but, as already noted, most of the literature on typically developing kindergarteners has concentrated on low-income children a category generally judged to be more at risk for school math underachievement, (e.g., Ramani & Siegler, 2008). A possible explanation for our findings is that the standard school activities carried out by the teachers are enough by themselves to bring children toward a high level of numeracy competence. Moreover, it is to be noted that our children came from a middle-class environment and likely had help from their families—in addition to standard schooling—in constructing sound initial math knowledge. When we discussed the matter with the teachers involved in the study, we learned that most of the children had received a relevant numeracy input from their parents. Many had been taught the Arabic digits from 1 to 9 and other numeracy skills. This factor may be important in young children's numerical development (Gunderson & Levine, 2011). Also, it may be that, during the standard kindergarten course, a good number of children can reach a significant level of math knowledge appropriate for their age group, even in the absence of supplemental training. The literature has shown that those children who have weaknesses in a skill benefit from empowerment training (Räsänen et al., 2009; Ramani & Siegler, 2011) and taking advantage of the "zone of proximal development" (Vygotsky, 1962). If children show a high level of performance in a skill we can hardly further strengthen that skill. In our study, children were assigned to one of the three experimental groups, depending on their grade of initial ability, so that the same numbers of high, low, and medium ability children were assigned to each group. A possible explanation for our finding may lie in the presence, in our sample, of children with high scores in early math abilities: some kindergarteners' early math high abilities may have hidden the effects of the training in enhancing early numerical competence.

To explore the possibility that training effects could have been hidden by the presence of children with high initial early math knowledge, and to test the hypothesis that the efficacy of an additional intervention is more accentuated in children with low early math abilities, we ran a further analysis in a subsample of low math ability children, in which we compared children who had undergone (training group) or not undergone (control group) math training. The results confirmed our hypothesis by showing that all low-ability children improved their performance, but, as expected, the training group significantly outperformed the control one. Our findings showed that, in low ability children, the supplemental intervention caused a significant early math ability improvement compared with the normal school curriculum. This result confirms, and extends to low ability middle-income children, the previous findings on low-income children related to the possibility of improving early numeracy skills in kindergarten children using numerical games and activities (e.g., Ramani & Siegler, 2008).

For low ability children, the standard school curriculum may not be sufficient as it is for average and high-achieving children, and it may be advisable, and even necessary in many cases, to develop an added intervention to support their early competence in mathematics.

One of our aims was to explore which kind of math training is most efficient for kindergarten children: the cooperative learning approach or the individual approach. Thus, this study contributes to the discussion about the efficacy of cooperative learning in children younger than six years of age. Our findings showed that the CL training pushed the children to a better performance than the individual training, but the difference between the two intervention approaches was not significant. This result runs counter to the notion that CL is more effective than other teaching approaches as the literature involving older children suggests (e.g., Johnson et al., 2008). As already stated, there is very little research investigating the role of collaboration in kindergarteners and, in the scarce literature, studies are often described without clear details about protocols utilized (e.g. Fuchs et al., 2001; Wiegel, 1998). A possible explanation for the lack of efficacy of CL in young children may relate to the nature of CL itself. When involved in a CL situation, students are requested to accomplish both teamwork and task work (Johnson et al., 2008). Teamwork involves complex social skills, such as communication, decision making, and conflict resolution skills. Task work involves the cognitive activities students had to accomplish. All these tasks may have been excessively demanding for such young children. For the effectiveness of CL versus individual training in children under six years of age, therefore, our data do not allow to draw a definite conclusion.

A limit of this study is the limited sample size. It may be interesting to replicate the study with a larger sample that includes both medium/high and low-ability children and to verify if a structured CL intervention can be more effective than individual training.

In conclusion, even taking into account the already mentioned limitation of the small sample size, our findings suggest that, at least when in the kindergarten curriculum early math teaching is comprised, standard teaching is probably enough to bring most kindergarteners to their highest “zone of proximal development” limit. However, even in a group of children from middle-income backgrounds, it is possible to find learners at a low starting level that can benefit from supplemental math training.

In future, it would be interesting to implement pre-math trainings by means of digital technologies. Until now there are few studies investigating the effectiveness of intervention programs on kindergarteners based on digital tools, and the few studies available highlighted the inconsistency of the results due mainly to the child’s difficulty to work without the constant monitoring of an adult (Stephen; Plowman, 2008). Nevertheless, the introduction of touch technology may open new possibilities in training very young children. In light of this novelty, the purpose of our next work is aimed to create new intervention protocols Information Communication Technology (ICT) based, targeting kindergarteners.

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