# THE DEVELOPMENT AND EMPOWERMENT OF MATHEMATICAL ABILITIES: THE IMPACT OF PENCIL AND PAPER AND COMPUTERISED INTERVENTIONS FOR PRESCHOOL CHILDREN

Maria Lidia Mascia[1], Mirian Agus[1], Maria Chiara Fastame[1], Maria Pietronilla Penna[1], Eliana Sale[1] and Eliano Pessa[2]

[1]*Department of Pedagogy, Psychology, Philosophy, University of Cagliari, Italy*

[2]*Department of Brain and Behavioural Sciences, University of Pavia, Italy*

**ABSTRACT**

The development of numerical abilities was examined in three groups of 5 year-olds: one including 13 children accomplishing a numerical training in pencil-and-paper format (EG1); another group including 21 children accomplished a homologous training in computerized format; the remaining 24 children were assigned to the control group (CG). The participants were assessed at three successive times (t0, t1 and t2) with a battery of validated tests assessing numerical abilities and fluid intelligence. At times t1 and t2 we found differences between experimental groups and CG, while the children's abilities in the two experimental groups were similar. We underline the crucial role of pre-syntactical and counting dimensions, accounting for a distinction between the experimental groups and control. Results are discussed with reference to the relevance for training activities of the presentation format (pencil-and-paper versus computer-assisted). Pragmatical and practical implications are also considered.

**KEYWORDS**

Early numeracy learning; Psychoeducational Training; Preschool; Cognitive Empowerment; Educational technology

## 1. INTRODUCTION

Many researchers are looking for exploring the basic structures that contribute to mathematical success in order to understand mathematical abilities development and to implement effective teaching strategies (e.g., Torbeyns, Gilmore, & Verschaffel, 2015; De Smedt, Noël, Gilmore, & Ansari, 2013). These studies evidenced the full complexity of mathematical acquisition processes starting from the preschool years. In this regard a growing body of studies has reported that early numeracy is developed during childhood even before the onset of formal education and it is progressively enriched at school (e.g., Jordan et al., 2009). Indeed, numerical processing is based on the development of two non-verbal mechanisms, such as the pre-verbal capacity to visually encode and enumerate a limited number of information (i.e., maximum 3-4 items), the so called Object Tracking System (Mandler & Shebo, 1982), and the capacity to discriminate two sets of items as a function of the number of elements expressing the quantity of each set (Approximate Number System; Dehaene, 2011). The latter capacity implies that when more than four items are presented and serial counting cannot be carried out, the capacity to visually enumerate the objects fails and counting responses become more fallacious. Overall, from a typically developmental perspective this impasse can be overcome only when young mathematics achievers learn a symbolic enumeration system and some counting skills, which allow those children to process the numerousness of unlimited sets of elements (e.g., Jordan et al., 2009).

However, further research shows that the development of mathematical skills predicts the successive mathematical achievements at school (e.g., Morgan, Farkas, & Wu, 2009) and the development of the related emotions, such as math anxiety, that is, the feeling of fear and tension interfering with mathematics performance (e.g., Jansen et al., 2013). For instance, early numeracy learning is slower in children attending primary school that successively are identified as students with dyscalculia (e.g., Passolunghi, Vercelloni, & Schadee, 2007). For this reason, during recent years the possibility of empowering early numeracy learning by structured early psycho-educational interventions received much attention. Indeed, researchers (e.g., Fuchs, 2009; Siegler & Ramani, 2009) argue that early psychoeducational programs promoting mathematics-related learning can be very useful both for typically developing children and those being unproficient mathematics achievers. The principle underpinning the early interventions for the empowerment of numeracy-related learning is that, from the one hand, they can strength the mathematics knowledge and skills of typically developed children and, from the other hand, they can provide an opportunity to improve mathematics skills of at-risk children, in order to reduce even the negative emotional impact of scholastic failure on them (e.g., Jansen et al., 2013; Siegler & Ramani, 2009). Some literature shows that trainings based on technology supports have a great importance in the development of many different kinds of learning abilities (Meneses et al., 2012). Most literature focuses the attention on the number line trainings, starting from the beneficial effect of paper–pencil tools on children's numerical development and their mathematics achievement (Moeller, Fischer, Nuerk, & Cress, 2015). This study underlines how computer-supported methods may considerably increase both the motivational aspect but also training efficiency in a great number of ways, for example implementing numerical trainings in general, ensuring adaptivity, accessibility and interactivity of training approaches. Some literature asserts that computer-assisted instruction is more effective and beneficial than traditional instruction for educating students (Gunbas, 2015).

Other studies state that the pencil-and-paper and psychoeducational programs have the same efficacy in the enhancement of cognitive functions in childhood (Penna, Stara, & Bonfiglio, 2002; Penna & Stara, 2010; Ramani, Siegler, & Hitti, 2012; Passolunghi & Costa, 2014). For instance, a series of follow-up studies reports that specific metacognitive and cognitive (e.g., visuo-spatial attention and working memory) psychoeducational trainings can be successfully used in formal education in order to promote the empowerment of specific cognitive processes underpinning learning in the classroom (e.g., Fastame & Callai, 2015). Previous research shows a correlation between individual differences in people's school math abilities and the accuracy with which they rapidly and nonverbally approximate how many items are in a scene (Libertus et al., 2011). A longitudinal study explores the importance of kindergarten measures of phonological awareness, working memory, and quantity-number competencies as predictors of mathematical school achievement in third graders (mean age 8,8 years) (Krajewski & Schneider, 2009). Moreover, a further body of studies shows the efficacy of pre-literacy psychoeducational interventions in improving early numeracy skills (e.g., classification, seriation, counting) of pre-schoolers (e.g., Agus et al., 2015; Cirino, 2011; Clements & Sarama, 2007). For instance, Clements and Sarama (2007) showed the effectiveness of an early numeracy learning intervention for young children lasted 26 weeks and based on a number of tasks such as counting, doing number comparison, and number recognition.

For what concerns the Italian scenario, during the last decade different psychoeducational trainings have been developed in order to empower numeracy knowledge and related skills. In this regard, very recently Agus et al. (2015) conducted a preliminary study combining two pencil-and-paper and computer-assisted psychoeducational interventions aimed at enriching numerical knowledge and visuo-spatial abilities in second graders. The authors found that the combination of both the pencil-and-paper and computer-assisted versions of visuo-spatial and mathematical interventions was more effective on the empowerment of numerical skills than the execution of single treatments.

The aim of this study was to verify the impact of two pencil-and-paper and computerized-assisted trainings on numerical intelligence of five years old children attending the last year of kindergarten. Specifically, we were interested in evaluating the effects of the presentation modality of the interventions in relation to the different aspects of numerical abilities (related to lexical, semantic, counting and pre-syntactical areas) and fluid intelligence empowerment.

Therefore, in agreement with the literature, we hypothesised that: 1) the children that carried out a computerized training display a greater enhancement in mathematical learning (Praet & Desoete, 2014) with respect to children lacking any form of specific psychoeducational training; 2) the participants that performed the training in both modalities could have an analogous improvement compared to that of the children carrying out only the computer-assisted tasks, because the effectiveness of both modalities might be related to the novelty of the resources/tasks used (Swanson & Hoskyn, 1998).

# 2. METHOD

## 2.1 Participants

Fifty-eight children, enrolled in the last year of kindergarten in several Italian schools, took part in the study after their parents had provided written informed consent for participation. This study is only a part of larger researches involving more than 300 children. The sample comprised typically developing children, showing no signs of cognitive or perceptual deficits. Four pupils were excluded from the starting sample because they presented some learning difficulties disabilities. The children assessed belonged to the middle socioeconomic status. The research was conducted on the base of the ethical requests defined by the Italian Association for Psychology. Table 1 summarizes the socio-demographic characteristics of participants; there were no differences in relation to the sex variable ($\chi^2$ = .557, df = 2, p = .757).

Table 1. Descriptive statistics in each group

| | | Control group (C) | Experimental groups | |
|---|---|---|---|---|
| | | | Training in pencil-and-paper format EG1 | Training in computerised form EG2 |
| PRE-TEST | N | 24 | 13 | 21 |
| | Percentage of women | 41.7 | 53.8 | 42.9 |
| | Age Mean in months at pre-test | 64.33 | 64.23 | 64.62 |
| | Age Standard deviation | 3.30 | 3.29 | 3.81 |
| | Lowest age | 58 | 59 | 59 |
| | Highest age | 70 | 70 | 71 |

## 2.2 Materials

Pupils were presented a standardized battery, constituted by the Raven's Colored Progressive Matrices (CPM, Raven, 1958) and by the BIN (Numerical Intelligence Scale; Molin, Poli, & Lucangeli, 2007), in order to have respectively a measure of fluid intelligence and of their numerical knowledge.

The CPM (Raven, 1958) are used also for children in kindergarten (Italian adaptation, Belacchi et al. 2008).

The BIN (Molin, Poli, & Lucangeli 2007) evaluates four areas of numerical skills: the lexical subscale (i.e., assessing the ability to read and write Arabic numbers, moreover the skill to join the number-word to the exact digit); the semantic subscale (i.e., evaluating the ability to associate numerical sizes, dots and Arabic digits); the pre-syntactical subscale (i.e., appraising the capability to link numbers to their number representation and to order several quantities); the counting subscale (i.e., assessing the ability to recite the number–words sequence forward and backward, as well as the knowledge of the order of Arabic digits from 1 to 5).

After the pre-test phase (t0), children in the first experimental group (EG1) underwent the training program "L'intelligenza numerica I" (Lucangeli, Poli, & Molin 2003) and 'Sviluppare l'intelligenza numerica I" (Lucangeli, Poli, & Molin 2010) in pencil-and-paper format. The remaining children were assigned to the second experimental group (EG2) that followed the homologous activities in computerized format ("Sviluppare l'intelligenza numerica I" by Lucangeli, Poli, & Molin 2010). The children in the control group (CG) carried out the regular curricular activities proposed by their teachers. The psychoeducational interventions employed in the current study consist of activities following the same conceptual and theoretical structure, developed to enhance numerical abilities in pre-schoolers pupils. The tasks were settled to empower and to favour a gradual and playful approach to the numerical knowledge in children, preparing them for primary school. The training enhances multiple processes: it favours the use of the Arabian code until 10, the learning of number names, the automation of the number sequence, the estimation of the weight of numbers, the evaluation of space, size and objects and the introduction of ordinality. Specifically, the software is composed of a series of tasks which are presented along the North Pole by an interactive tutor; he explains the instructions, gives feedbacks about the correctness of the performance and encourages the user in case of failure. The level of difficulty of those tasks might be adjusted in order to adapt them to the efficiency of the user.

Similarly, the pencil-and-paper program was aimed at enriching numerical knowledge, following the same principles. The program includes different units and learning situations, characterised by new elements and increasing complexity, organised in a series of printable worksheets for the activities. The pencil-and-paper activities were conducted by trained researchers. Both the computer-assisted and pencil-and-paper programs include several exercises promoting the metacognitive awareness and control of the cognitive processes involved in the activities.

## 2.3 Procedure

At pre-test (t0), post-test (t1) and follow up (t2), children were tested individually in two sessions, lasting approximately each twenty minutes. Each test was presented following the instructions contained in the original manuals (Belacchi et al., 2008; Molin, Poli, & Lucangeli, 2007). After the pre-test phase, 13 children (6 males and 7 females; M age =64.23, SD =3.2 months) were randomly extracted from the original sample and were presented the training activities in pencil-and-paper format (EG1), selected from "L'intelligenza numerica I" (Lucangeli, Poli, & Molin 2003) and 'Sviluppare l'intelligenza numerica I" (Lucangeli, Poli, & Molin 2010). At the same time, 21 children (12 males and 9 females, M age = 64.62, SD = 3.81 months) were assigned to the second experimental group (EG2) that accomplished the homologous training in computerized format (Lucangeli, Poli, & Molin 2010). The remaining 24 children (14 males and 10 females M age = 64.33, SD = 3.3 months) were assigned to the control group (CG) that carried out the regular curricular activities proposed by their teachers. The groups were matched for chronological age. At the present, it should be stressed that the children in the experimental groups attended different schools from those in the control group. However, their socio-cultural context was similar, because the schools were located in neighboring villages.

In the first experimental group (EG1) the pupils engaged in the pencil-and-paper activities that were carried out collectively during 10 weekly sessions that lasted approximately one hour each. On the other hand, each child in the second experimental group (EG2) was individually trained by the homologous computer-assisted intervention, for 10 weekly sessions, lasting 30 minutes each. When the trainings were concluded (i.e., t1 - post-test after 3 months of the same scholastic year) and also after 6 months from the post-test phase (i.e., t2 - follow-up at the June of the same scholastic year), two further abilities assessments of the sample were carried out. Specifically the post-test was applied in all groups that were presented the same battery of tests originally administered at the pre-test – t0; the follow-up valuation was realized in two experimental groups (EG1 and EG2).

## 2.4 Data Analysis

In order to verify the hypotheses of research, the potential differences between groups at pre-test in each dimension were assessed. For this purpose, a series of univariate Analyses of Variance (ANOVAs) were carried out on the scores calculated at pre-test, using the training group as factor (CG, EG1, EG2). All variables achieved the rules of the ANOVA application. These analyses did not revealed any significant statistical difference between the experimental groups and the control one in the CPM test [F=. 914; df=2;55; p= .407], BIN Lexical [F=. 217; df=2;55; p= .806], BIN Semantic [F=. 137; df=2;55; p= .872], BIN Counting [F=2.308; df=2;55; p= .109] and BIN Pre-Syntactical [F=. 544; df=2;55; p= .583].

On the bases of these outcomes, it was settled to investigate the information related to the effect of trainings in the groups at post-test and follow up (Keppel, 1991). Then the specific parametric statistical analyses were applied in order to verify the hypotheses, controlling the effect of age. Firstly the linear correlations were evaluated between all pairs of variables (at t0, t1 and t2) by the application of Pearson's r Coefficient. Formerly, to assess the specific role of trainings in the change of performance from pre-test to post test (in each dimension evaluated), a Multivariate Mixed design Analysis of Covariance was computed, where the repeated measures were constituted by the performances in two times (t0 pre-test - t1 post-test), the between factor was the "training group" (control group, experimental pencil-and-paper, experimental computerized) and the covariate was the age at pre-test. The application of this statistics was suitable in order to compare the performances in all scales for all groups in two moments, controlling the effects of influencing factors. Consequently, another Multivariate Mixed design Analysis of Covariance was performed in order to evaluate if there was a retaining of achievements from the post-test (t1) until the follow up assessment (t2); then this analysis focused on the specific performances of experimental groups. Subsequently, a Discriminant Function Analysis was applied in order to identify the variables more useful in making the distinction among children in CG, EG1 and EG2. This analysis allowed to select the dimensions that better predict the probability of a child to belong to one specific group, useful to interpret group differences.

## 3. RESULTS

The first Multivariate Mixed design Analysis of Covariance was applied on all dimensions taken in account (CPM and BIN scales); the repeated measures were the pre-test and post-test assessments (t0 and t1), the between factor was the training group (CG, EG1, EG2) and the covariate was the age at pre-test (Table 2). A significant effect of the repeated measures was found [$F= 5.521$, df= 1;54, $p=.022$, $\eta^2= .093$] at t0 and t1, highlighting that in post-test condition there are generally scores higher than at the pre-test. Moreover, it was also observed a significant interaction effect between the repeated measures (i.e., t0 vs. t1) and training groups (i.e., CG vs., EG1 and EG2) [$F= 4.787$, df= 2;54, $p=.012$, $\eta^2= .151$], that is, at post-test the scores of EG1 and EG2 are significantly higher than those of CG (Table 2).

Table 2. Results of Multivariate Mixed Design Ancova comparing pre-test and post-test in groups CG, EG1, EG2

| Source | Wilks' Lambda | df | F | p | Eta$^2$ | Bonferroni's Adjusted Group comparisons |
|---|---|---|---|---|---|---|
| t0-t1 | .907* | 1 | 5.521 | .022ǂ | .093 | t0 <t1 |
| t0-t1 * age | .938 | 1 | 3.570 | .064 | .062 | ns |
| t0-t1 * training | .849* | 2 | 4.787 | .012ǂ | .151 | at t1 CG < EG1 and CG < EG2 |
| scale | .977 | 4 | .260 | .903 | .005 | ns |
| scale*age | .965 | 4 | .317 | .803 | .006 | ns |
| t0-t1 * scale | .933 | 4 | .715 | .583 | .013 | ns |
| t0-t1 * scale * age | .945 | 4 | .584 | .674 | .011 | ns |
| t0-t1 * scale * training | .865 | 8 | .844 | .565 | .030 | ns |

Note: ǂ ǂ p < .01 ǂ p<.05 ns= not significant

In order to focus on the effects of trainings, another Multivariate Mixed Design Ancova was applied, using the scores at post-test and follow up (t1 and t2) as repeated measures. The training groups (EG1 and EG2) as between factor and the age at pre-test as covariate. This analysis did not show any significant effect, emphasizing the preservation of cognitive achievement reached by the trainings, six months after the end of programs in paper-and-pencil and computerised formats (Table 3).

Then, a Discriminant Function Analysis was performed in order to identify the variables discriminating the participants across the groups. We evaluated the issues related to the sample size, multivariate normality and multicollinearity (Huberty, 2005). In particular we met the criterion requiring that the size of the minutest group must be above the number of variables used as predictors. The discriminant function analysis was applied (Stepwise method) using CPM score and BIN subscales. The Box's M statistic was not significant ($p =.719$), guaranteeing that the homogeneity of variance assumption was satisfied. At the last analysis step, the scales comprised in the unique significant function were the post-test BIN Pre-syntactical and post-test BIN Counting (Wilks' $\lambda = .849$, $p<.0001$), indicating that these two dimensions are discriminating the groups. Moreover, the discriminant function analysis had a reliable association with the training groups [$\chi^2 =20.731$, df=4, $p < .001$]. The function with the scales mentioned above was able to appropriately classify into groups totally 58.6% of participants [specifically the 70.8% of the CG (i.e. 17/24), the 38.5% of EG1 (i.e. 5/13) and the 57.1% of EG2 (12/21)].

Table 3. Results of Multivariate Mixed Design Ancova comparing post-test and follow up in the groups EG1, EG2

| Source | Wilks' Lambda | df | F | p | $Eta^2$ | Bonferroni's Adjusted Group comparisons |
|---|---|---|---|---|---|---|
| t1-t2 | .913 | 1 | 2.557 | .121 | .087 | ns |
| t1-t2 * age | .908 | 1 | 2.720 | .111 | .092 | ns |
| t1-t2 * training | .965 | 1 | .971 | .333 | .035 | ns |
| scale | .872 | 4 | .976 | .424 | .035 | ns |
| scale*age | .851 | 4 | 1.123 | .343 | .040 | ns |
| t1-t2 * scale | .835 | 4 | 1.105 | .355 | .039 | ns |
| t1-t2 * scale * age | .837 | 4 | .987 | .410 | .035 | ns |
| t1-t2 * scale * training | .849 | 4 | 1.450 | .229 | .051 | ns |

Note: ns= not significant

## 4. DISCUSSION AND CONCLUSIONS

A wide literature states that psychoeducational trainings have some advantages and the same specific training can be settled and presented in two formats: computerized or pencil-and-paper (Penna, Stara, & Bonfiglio 2002). In the pencil-and-paper format, for example, an important aspect can be the novelty, which could be identified in the presence of a new teacher, specialized in the promotion of training activities (Slavin, 2013; Agus et al., 2015). Educational technology is defined as a set of electronic tools and applications that help deliver learning materials and support learning processes to improve learning goals (Afshari et al., 2009, Meneses et al., 2012). Then technology can play a role in promoting an especially propulsive greater adaptability of the education system and in opening it to a range of values and attitudes as diversification of preparations, self-learning ability, aptitude confrontation and cooperation, ability to exploration and research (Vanderlinde, Aesaert, & Van Braak, 2014).

This study shows the efficacy of both computer-assisted and pencil-and-paper trainings in enriching fluid and numerical intelligences. Indeed, differences between the experimental groups that use different training formats were not found. If there aren't significative differences, the training with jcomputer technology opens up new directions for the successful training of numerical competencies that should be pursued as they may be particularly beneficial for those with special needs in numerical/mathematical learning.

Overall, these outcomes, highlighted also by the discriminant analysis, underline the importance of the contents but not of the presentation modality in empowering early numeracy learning (Leh, 2011). Toll and Van Luit (2012) documented the validity of a psychoeducational intervention empowering reasoning, measuring, calculation, use of abstract symbols and number line skills that was developed for kindergarteners with mathematical problems. From an applied perspective, this is very crucial, because the benefits of early numeracy learning interventions in preschoolers at risk of developing mathematical learning difficulties can be already evident when those children attend the first grade of primary school (Dowker & Sigley, 2010). Since there is a high variability in pre-schoolers' mathematics skills, during the last decades a series of trainings has been developed in order to enhance numerical knowledge in early childhood, that is, to promote early numeracy learning especially in low-performing learners (Riccomini & Smith, 2011). Indeed, according to Clarke et at. (2006) the implementation of specific computer-assisted and/or pencil-and-paper interventions, mainly based on the use of explicit and simple instructions, on the employment of visual materials (e.g., cubes, number lines) and demonstrations about how to solve a problem, on breaking complex tasks in simpler units, seem to favour the empowerment of numeracy skills in early childhood, especially in kindergarten children at risk for severe mathematics problems.

Another element of interest is given by the results of the discriminant analysis. This evaluation highlighted that the values of pre-syntactical and counting scales are discriminant (Molin, Polin, & Lucangeli, 2007), distinguishing among experimental and control groups. Indeed, applying this function, the correct classification of group membership appears high in relation to CG, that is, in a condition in which children showed lower scores compared to those of the participants of the experimental groups. Also this fact confirmed the opportunity of differentiating between CG and experimental groups, but not in terms of the modality (i.e., computer-assisted vs. pencil-and-paper) in which the psychoeducational intervention was proposed (Penna & Stara, 2010). In agreement with previous authors (Swanson & Hoskyn, 1998), the effectiveness of the training in both modalities might be related to the novelty of resources used and to the overall educational approach applied to elicit the empowerment of numeracy learning (Swanson & Hoskyn, 1998). Furthermore, the efficacy of our psychoeducational intervention can be also related to the fact that it is aimed at empowering the metacognitive knowledge in numeracy learning. This is very relevant, because as In agreement with our results we can suppose that, as stated in the literature, what is important in order to assess the efficacy of an intervention is not the modality used, but the positive or negative effects on the child intelligence and learning (Penna & Stara, 2010).

Concerning the limits of this work and the future developments, we think that it would be useful to deepen the analysis of the amount of achieved learning by using additional assessment tools. These tools should be appropriate to the recognition of the potential specificities linked to the two different training modalities (i.e., paper-and-pencil and computerized).

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## REFERENCES

Agus, M., et al., 2015. The measurement of enhancement in mathematical abilities as a result of joint cognitive trainings in numerical and visualspatial skills: A preliminary study. *Journal of Physics: Conference Series*, 588. Available at: http://iopscience.iop.org/1742-6596/588/1/012041.

Afshari, M. et al., 2009. Factors Affecting Teachers’ Use of Information and Communication Technology. *Online Submission*, 2(1), pp.77–104.

Belacchi, C., et al., 2008. *Manuale CPM*, Organizzazioni Speciali.

Cirino, P.T., 2011. The interrelationships of mathematical precursors in kindergarten. *Journal of experimental child psychology*, 108(4), pp.713–33.

Clarke, B., Cheeseman, J. & Clarke, D., 2006. The mathematical knowledge and understanding young children bring to school. *Mathematics Education Research Journal*, 18(1), pp.78–102.

Clements, D.H. & Sarama, J., 2007. Effects of a Preschool Mathematics Curriculum: Summative Research on the Building Blocks Project. *Journal for Research in Mathematics Education*, 38(2), pp. 136–163.

De Smedt, B., Noël, M. P., Gilmore, C., & Ansari, D., 2013. The relationship between symbolic and non-symbolic numerical magnitude processing skills and the typical and atypical development of mathematics: a review of evidence from brain and behavior. *Trends in Neuroscience & Education*, 2, pp. 48-55.

Dehaene, S., 2011. *The number sense: How the mind creates mathematics*, Oxford University Press.

Dowker, A. & Sigley, G., 2010. Targeted interventions for children with arithmetical difficulties. *British Journal of Educational Psychology*, 2(7), p.65.

Fastame, M.C. & Callai, D., 2015. Empowering visuo-spatial ability in primary school: results from a follow-up study. *Educational Psychology in Practice*, 31(1), pp.86–98.

Fuchs, L.S., 2009. Mathematics intervention at the secondary prevention level of a multi-tier prevention system: Six key principles. *RtI Action Network*, 9, p.2010.

Gunbas, N., 2015. Students’ mathematics word problem-solving achievement in a computer-based story. *Journal of Computer Assisted Learning*, 31(1), pp.78–95.

Huberty, C.J., 2005. *Discriminant analysis*, Wiley Online Library.

Jansen, B.R.J. et al., 2013. The influence of experiencing success in math on math anxiety, perceived math competence, and math performance. *Learning and Individual Differences*, 24, pp.190–197.

Jordan, N.C. et al., 2009. Early math matters: kindergarten number competence and later mathematics outcomes. *Developmental psychology*, 45(3), p.850-867.

Keppel, G., 1991. *Design and analysis: A researcher's handbook.* Prentice-Hall, Inc.

Krajewski, K., & Schneider, W., 2009. Exploring the impact of phonological awareness, visual–spatial working memory, and preschool quantity–number competencies on mathematics achievement in elementary school: Findings from a 3-year longitudinal study. *Journal of experimental child psychology*, 103(4), pp. 516-531.

Leh, J., 2011. *Mathematics Word Problem Solving: An Investigation into Schema-Based Instruction in a Computer-Mediated Setting and a Teacher-Mediated Setting with Mathematically Low-Performing Students.* ProQuest LLC. 789 East Eisenhower Parkway, PO Box 1346, Ann Arbor, MI 48106.

Libertus, M. E., Feigenson, L., & Halberda, J., 2011. Preschool acuity of the approximate number system correlates with school math ability. *Developmental Science*, 14(6), pp. 1292-1300.

Lucangeli, D., Poli, S. & Molin, A., 2003. *L'intelligenza numerica*, Edizioni Erickson.

Lucangeli, D., Poli, S. & Molin, A., 2010. *Sviluppare l'intelligenza numerica I*, Edizioni Erickson.

Mandler, G. & Shebo, B.J., 1982. Subitizing: an analysis of its component processes. *Journal of Experimental Psychology: General*, 111(1), p.1.

Meneses, J. et al., 2012. Internet in teachers' professional practice outside the classroom: Examining supportive and management uses in primary and secondary schools. *Computers & Education*, 59(3), pp.915–924.

Moeller, K., Fischer, U., Nuerk, H. C., & Cress, U., 2015. Computers in mathematics education–Training the mental number line. *Computers in Human Behavior*, 48, pp. 597-607.

Molin, A., Poli, S. & Lucangeli, D., 2007. *Batteria Intelligenza Numerica 4-6 [Battery for Numerical Intelligence]*, Edizioni Erickson.

Morgan, P.L., Farkas, G. & Wu, Q., 2009. Five-Year Growth Trajectories of Kindergarten Children With Learning Difficulties in Mathematics. *Journal of Learning Disabilities, 42(*4), pp. 306-321.

Passolunghi, M.C., Vercelloni, B. & Schadee, H., 2007. The precursors of mathematics learning: Working memory, phonological ability and numerical competence. *Cognitive Development*, 22(2), pp.165–184.

Passolunghi, M.C., & Costa, H.M., 2014. Working memory and early numeracy training in preschool children. *Child Neuropsychology*, (ahead-of-print), pp. 1-18.

Penna, M.P. & Stara, V., 2010. Opinions on computers, and efficacy of a computer-based learning: A pilot study. *Education and Information Technologies*, 15(3), pp.181–204.

Penna, M.P., Stara, V. & Bonfiglio, N., 2002. A systemic proposal on the use of a new technology as a learning tool in school context. In *Emergence in Complex, Cognitive, Social, and Biological Systems*. Springer, pp. 153–157.

Praet, M. & Desoete, A., 2014. Enhancing young children's arithmetic skills through non-intensive, computerised kindergarten interventions: A randomised controlled study. *Teaching and Teacher Education*, 39, pp.56–65.

Ramani, G. B., Siegler, R. S., & Hitti, A., 2012. Taking it to the classroom: Number board games as a small group learning activity. *Journal of educational psychology,* 104(3), pp 661-672.

Raven, J.C., 1958. *Guide to using the Coloured Progressive Matrices*, Oxford, England: H. K. Lewis & Co.

Riccomini, P.J. & Smith, G.W., 2011. Introduction of response to intervention in mathematics. In R. G. & R. Newman-Gonchar, ed. *Understanding RTI in Mathematics. Proven methods and applications*. Baltimore: Paul H. Brookes Publishing Co, pp. 1–16.

Siegler, R.S. & Ramani, G.B., 2009. Playing linear number board games—but not circular ones—improves low-income pre-schoolers' numerical understanding. *Journal of Educational Psychology*, 101(3), p.545-560.

Slavin, R.E., 2013. Effective programmes in reading and mathematics: lessons from the Best Evidence Encyclopaedia 1. *School Effectiveness and School Improvement*, 24(4), pp.383–391.

Swanson, H.L. & Hoskyn, M., 1998. Experimental Intervention Research on Students with Learning Disabilities: A Meta-Analysis of Treatment Outcomes. *Review of Educational Research*, 68 (3), pp.277–321. Available at: http://rer.sagepub.com/content/68/3/277.abstract.

Torbeyns, J., Gilmore, C., & Verschaffel, L., 2015. The Acquisition of Preschool Mathematical Abilities: Theoretical, Methodological and Educational Considerations. *Mathematical Thinking and Learning*, 17(2-3), pp. 99-115.

Toll, S.W.M. & Van Luit, J.E.H., 2012. Early Numeracy Intervention for Low-Performing Kindergartners. *Journal of Early Intervention*, 34 (4), pp.243–264.

Vanderlinde, R., Aesaert, K., & van Braak, J., 2014. Institutionalised ICT use in primary education: A multilevel analysis. *Computers & Education*, 72, pp. 1–10.

Xenidou-Dervou, I., De Smedt, B., van der Schoot, M., & van Lieshout, E. C. D. M., 2013. Individual differences in kindergarten math achievement: The integrative roles of approximation skills and working memory. *Learning and Individual Differences*, 28, pp. 119–129.