Educational, Cultural and Psychological Studies

JOURNAL of

31
June 2025

Studi e Contributi di Ricerca
Studies and Research Contributions

Note di Ricerca

Research Notes

Online ISSN 2037-7924 - Print ISSN 2037-7932 - ISBN 978-88-5513-208-4

Effects of the *Enactive, Iconic, Symbolic* (EIS) Intervention on Student Math Skills in Primary School *

Marta Pellegrini [1] - Valeria Di Martino [2]
Roberto Trinchero [3]

[1] *Università degli Studi di Cagliari - Department of Education, Psychology and Philosophy (Italy)*

[2] *Università degli Studi di Palermo - Department of Psychology, Educational Science and Human Movement (Italy)*

[3] *Università degli Studi di Torino - Department of Philosophy and Education Sciences (Italy)*

DOI: https://doi.org/10.7358/ecps-2025-031-pell

marta.pellegrini@unica.it
valeria.dimartino@unipa.it
roberto.trinchero@unito.it

EFFETTI DEL PROGRAMMA «ENATTIVO, ICONICO, SIMBOLICO» (EIS) SULLE COMPETENZE MATEMATICHE DEGLI STUDENTI NELLA SCUOLA PRIMARIA

Abstract

«Enactive, Iconic, Symbolic» (EIS) is a recently developed program modeled after instructional methodologies used in the Singapore math approach. The intervention emphasizes sequential mastery of math concepts, problem solving, and the use of the Concrete to Pictorial to Abstract approach (CPA). This quasi-experimental study evaluates the impact of EIS program on student math performance to explore the applicability of

* This paper is the result of the joint work of the authors. Specifically, sections 3.2, 3.6, 4 and 5 are attributed to M. Pellegrini; sections 1, 1.1, 2, 3.1, 3.5, and 6 to V. Di Martino; sections 3.3 and 3.4 to R. Trinchero.

the Singapore approach in the Italian context and define the most appropriate methods for future large-scale evaluations. Eleven third- through fifth-grade treatment classes were matched comparison classes using propensity score matching, with mathematics performance measured before and after the intervention. A two-level random intercept hierarchical linear model was used to estimate treatment impact. We found no statistical significance effects of EIS after 16-20 weeks, ranging between 0.12 to 0.35 standard deviation units. The findings suggest the need for further investigations through large-scale evaluations.

Keywords: Classroom instruction; Math skills; Primary school; Quasi-experimental design; Singapore math.

1. Introduction

International assessments have highlighted the differences in academic performance among countries on a global scale. East Asian nations have consistently excelled in these assessments, particularly in mathematics. Singapore is currently first in the most recent ranking of the Program for International Student Assessment (PISA) (OECD, 2023) for student proficiency levels and is the top nation in the Trends in Mathematics and Science Study (TIMSS) 2019 (Mullis *et al.*, 2020). According to this latest assessment, half of fourth-grade students in Singapore reached an advanced level of proficiency, enabling them to successfully solve complex problems (Kaur, 2021). In contrast, most of the 64 participating countries fell under 10% of students reaching that level. Within Europe, countries like France, Italy, and Spain found themselves at the lowest end of the ranking, with just 4% of students achieving proficiency at an Advanced level (Mullis *et al.*, 2020).

These results have drawn the attention of policymakers in countries performing below average, who felt the urgency to develop and implement effective teaching approaches to raise student math proficiency. They looked at the Singapore approach to teaching mathematics as a potential model for adaptation in Western countries. In 2016, the U.K. Government allocated £41 million in funding to support schools in embracing mastery-based teaching methods inspired by Shanghai and Singapore (Jerrim & Vignoles, 2016; Lindorff *et al.*, 2019).

Evidence to support the transferability of the Singapore approach beyond the specific national context is limited but promising in terms of effects on student math performance in primary school. The U.S. *Math* *in Focus* curriculum was evaluated by three experimental or quasi-experimental studies, while the U.K. *Inspire Math* curriculum was evaluated in one mixed-methods cluster randomized controlled trial. The three *Math in Focus* studies were included in the Best Evidence Encyclopedia (Pellegrini *et al.*, 2021), a widely recognized resource evaluating the strength of the evidence for various educational programs in K-12. The two studies by ERIA (2010, 2013) were quasi-experimental evaluations in third and fourth grades, showing large average effects with effect sizes (ES) of 0.25 ($p < .05$) and 0.29 respectively. The most rigorous evaluation using a random sample was conducted by Jaciw *et al.* (2016) in third through fifth grades, with significant effects on problem solving (ES = 0.12) and procedures (ES = 0.14). Lindorff *et al.* (2019) evaluated the impact of *Inspire Math* in the U.K. The intervention was implemented in 12 schools for three months and results showed a significant effect on student math achievement at the end of term 3 (ES = 0.42, $p < .05$).

In the Italian educational context, mathematics performance has been a persistent concern. National assessments conducted by INVALSI (National Institute for the Evaluation of the Education System) have consistently shown geographical disparities and overall performance below satisfactory levels (INVALSI, 2024). Italian research has identified several factors contributing to these challenges, including traditional teaching approaches that emphasize procedural knowledge over conceptual understanding (Zan, 2011) and difficulties in mathematical problem solving instruction (Di Martino, 2015; Zan, 2016). These findings align with international research suggesting that instructional approaches emphasizing deep conceptual understanding and systematic problem solving strategies, such as those found in high-performing East Asian nations, could potentially address similar challenges in different cultural contexts (Spagnolo & Di Paola, 2010; Bartolini Bussi *et al.*, 2013).

This article reports results from a quasi-experimental design to evaluate the first Italian teaching intervention inspired by the principles of the Singapore approach, conducted as part of the activities of the Society for Learning and Instruction Informed by Evidence (S.Ap.I.E.). After the development of the *Enactive, Iconic, Symbolic* (EIS) intervention, we conducted this preliminary evaluation in third through fifth grades across Italy, with the following purposes: (i) to investigate whether an adaptation of the Singapore math approach is suitable in the Italian school context and leads to improvements in student math performance; (ii) to gather data to revise the EIS intervention for making it available for schools; and (iii) to define the most appropriate methods for future large-scale evaluations.

1.1. *The Singapore math approach and adaptations*

Starting from the late 1980s, the Ministry of Education in Singapore has promoted a structured educational curriculum for primary and secondary education to be used nationally, with a strong emphasis on *problem solving* and *mental math skills*. This approach is firmly rooted in the Pentagon theoretical framework, in which problem solving is central and shaped by five components: concepts, skills, processes, metacognition, and attitudes. The framework prioritizes a more in-depth exploration of fewer math topics and promotes the idea of *mastery learning*. Instead of moving on to new topics quickly, students are expected to fully understand and master a concept before moving on to the next. Furthermore, concepts are introduced at a basic level and gradually deepened over time in a *spiral progression*, reinforcing learning and supporting students in making connections between different mathematical concepts (Ng & Lee, 2009; Lee *et al.*, 2020). All five framework components are interrelated and needed to develop problem solving skills (Singapore Ministry of Education, 2006). According to Kaur (2019), problem solving functions as an active knowledge-building process where students engage deeply with mathematical concepts rather than passively receiving information. This approach emphasizes conceptual understanding as a prerequisite to procedural fluency, ensuring that students grasp the underlying mathematical principles before moving on to computational procedures or algorithmic solutions. Lee *et al.* (2021) emphasize how the curriculum incorporates authentic problem solving scenarios that bridge classroom mathematics with everyday experiences, developing students' ability to transfer mathematical knowledge to practical situations. Within this framework, problem solving simultaneously functions as the goal to be achieved, the method through which learning occurs, and the set of skills to be developed (Toh *et al.*, 2019).

At the core of Singapore math is the *Concrete-Pictorial-Abstract approach* (CPA), including (i) a *Concrete* stage, in which students use physical objects, such as cubes or counters, to explore mathematical concepts. By manipulating tangible items, students develop a concrete understanding of the underlying principles; (ii) a *Pictorial* stage, in which students progress to using visual representations to solve problems. These visual aids help bridge the gap between the concrete and abstract levels and enable students to visualize and solve complex problems; (iii) an *Abstract* stage, which involves students transitioning to working with symbols and numbers. This approach draws its theoretical foundation from the work of Bruner (1966), who proposed three modes of representations to process information, from concrete experiences to abstract thinking. This sequence starts with the action-based mode by engaging students with physical objects (*enactive*), progresses to visual representations of concepts or objects (*iconic*), and eventually leads to abstract representations such as words and mathematical notations (*symbolic*). Empirical evidence supports the effectiveness of the CPA model with the whole class, and with students who struggle in mathematics, as demonstrated in various studies (e.g., Chang *et al.*, 2017; Salingay & Tan, 2018; Purwadi *et al.*, 2019). The CPA model provides a comprehensive and effective approach to teaching mathematics, fostering a deep understanding of mathematical concepts and problem solving skills.

2. Research objectives and hypothesis

In the current study, we conducted a small-scale test of the methods and procedures to be used on a larger scale in order to understand whether the Singapore math approach can be used successfully in Italy (Porta, 2008). This pilot evaluation aimed to (i) explore the suitability of the Singapore math approach in the Italian primary school context, gauging student math performance; (ii) define the most appropriate methods and procedures for future large-scale evaluations. On the basis of previous studies on the adaption of Singapore math approach in the U.S. and U.K. (ERIA, 2010, 2013; Jaciw *et al.*, 2016; Lindorff *et al.*, 2019), we hypothesize that students in EIS group will outperform students in the comparison group. However, due to the small sample size involved in this study, we expect to detect no statistically significant effects.

3. Method

3.1. *Design*

We used a quasi-experimental pretest-posttest control group design, in which intervention classes were matched to comparison classes prior to the beginning of the intervention based on pretest scores, grade level, and gender (Shadish *et al.*, 2002). Randomization was precluded in our study due to ethical concerns raised by school principals. Concerns were expressed regarding potential inequity arising from the random assignment of classes to interventions. Consequently, we adopted a matched control group design in which teachers who agreed to receive the program were matched with their classes to comparison classes following regular teaching practice.

3.2. *Participants*

Schools were recruited in eight Italian regions, located in urban and rural areas. Schools in rural areas usually have a smaller class size, resulting in a mean of 15 students per class. The initial population of students consisted of 73 classes that agreed to take part in the study. Eleven teachers and their students (*n* = 181) in third to fifth grade were willing to receive the treatment, and their classes were matched to 11 comparison classes (*n* = 148) drawn from similar schools. Among the participating students, the mean age was nine, and half of them were female. Students with medium and severe intellectual disabilities were provided with different materials during the class activities and were not included in the sample. Characteristics of the final analytical sample (278 students) are shown in *Table 1*.

Table 1. – Descriptive characteristics and pretest scores by group for the analytical sample.

	Comparison (*n* = 116)	EIS (*n* = 162)	SMD for pretest
	n (%)	*n (%)*	
Gender			
Female	63 (54.3)	87 (53.7)	
Grade			
Third	16 (13.8)	31 (19.1)	
Fourth	58 (50.0)	79 (48.8)	
Fifth	42 (36.2)	52 (32.1)	
	M (SD)	*M (SD)*	
Age	9.21 (0.69)	9.08 (0.76)	
Pretest			
SPM	44.7 (9.76)	43.0 (8.71)	-0.18
General Math	4.89 (2.48)	4.69 (2.30)	-0.08

Note: SMD = Standardized Mean Difference; M = Mean; SD = Standard Deviation; n = Number of students; SPM = Test of Mathematical Problem Solving Abilities.

3.3. *The EIS intervention*

We developed the EIS intervention for third, fourth, and fifth grades for a total of 12 lessons, with related materials for each grade. A single lesson can extend over several days, giving students diverse opportunities to learn and apply a specific concept, with the aim of leading to mastery. The topics addressed in the intervention were selected to align with the objectives outlined in the National Guidelines provided by the Italian Ministry of Education for each grade level. The EIS activities were designed with the following principles:

- Helping students to develop strong mathematical reasoning, problem solving skills, and a deep understanding of mathematical concepts.
- Engaging students in problem solving activities that encourage them to approach and solve real-world problems using the strategies they have learned.
- Focusing on mastering each mathematical concept before moving on to the next. This ensures a strong foundation for students to tackle more advanced mathematical concepts in the future.
- Supporting students in exploring mathematical concepts using the CPA stages: manipulating tangibles items (concrete stage), using visual representations (pictorial stage), working with symbols (abstract stage).

Five phases are the basis of EIS lessons (exploration, review, generalization, guided practice, and independent practice) and these are presented in *Table 2*.

While the EIS approach incorporates elements of explicit instruction through teacher guidance, it aims to balance teacher-centered and student-centered learning experiences. During the exploration phase, students engage in challenges before formal teacher instruction, a practice that promotes sense-making and metacognitive awareness (Kapur, 2016). The role of the teacher shifts from being facilitator during the exploration to guide during the review and generalization phases, and finally to supporter during independent practice. This flexible positioning aligns with research on adaptive teaching (Anthony & Walshaw, 2009) and enables responsive instruction tailored to student needs. The approach emphasizes student agency by encouraging multiple solution strategies and fostering mathematical discussions through peer collaboration. Students are consistently encouraged to reflect on their problem solving processes and verbalize their thinking strategies, and monitor their understanding (Schoenfeld, 2016).

Table 2. – Overview of the phases of the EIS program.

Phase	Description
Exploration	The teacher organizes the students into heterogeneous pairs, in terms of mathematical achievement, taking care to ensure compatibility between the two members of each pair. The teacher presents a problem that engages the enactive, iconic, and symbolic aspects, aimed at eliciting the students' current pre-knowledge about the topic, which will be explained later. In this phase, the teacher moves around the class observing the proposed solutions and the strategies adopted by the students, as well as identifying the different methods used by the students to solve it. In most cases, the problems allow for multiple solutions or, alternatively, a single solution reached through various approaches.
Review	The teacher asks the students to verbalize the process used to solve the problem. When necessary, the teacher provides immediate feedback to correct any misconceptions or mistakes. The main purpose of this feedback is to guide the students away from incorrect paths and towards ones that potentially lead to the solution of the problem.
Generalization	Following the review phase, a description of the appropriate method or methods for solving the problem is provided to the class.
Guided practice	The teacher provides exercises aimed at reinforcing the solutions illustrated in the generalization phase. The activities gradually progress towards more complex tasks. The use of concrete materials to help the students in solving the problem is encouraged. The teacher supports them in completing the exercises and provides feedback if difficulties arise.
Independent practice	The teacher provides increasingly abstract problems, meant for students to practice independently. Students usually work on the tasks individually but have the option to seek help from classmates or teachers if they face any challenges. The teacher may also decide to make students facing difficulties work in pairs. Nevertheless, it is important for students to understand that the ultimate goal is to become independent in problem solving. Following the independent practice, the teacher provides feedback on the students' work.

3.4. *Outcome measures*

Two measures were administered at the pretest and posttest stages to gauge the impact of EIS on students' mathematics performance. The General Math measure, developed by the research team, aims to evaluate the mathematical knowledge and skills of students directly trained in the EIS program. This measure was administered to collect results relevant to revising and improving the intervention. It consists of 15 items that propose math tasks to be solved by the students, with four options each. For each grade level, these items cover the topics taught in the intervention.

The Test of Mathematical Problem Solving Abilities (SPM Test, Lucangeli *et al.*, 2003) is a standardized Italian measure designed to assess students' ability to approach and solve mathematical word problems. The test includes four word problems for each grade (three for third grade), covering comprehension, representation, categorization, planning, and evaluation components. Each item includes four response options: irrelevant, incorrect, partial, and correct. We selected the SPM Test for two reasons. First, we aimed to gauge the impact on the problem solving skills that are central in the EIS intervention and more general in the Singapore approach. Second, we sought to include at least one measure that was developed independently from our research team, to mitigate any potential influence on effect sizes, as suggested by previous research (Cheung & Slavin, 2016; Wolf & Harbatkin, 2023).

3.5. *Procedure*

The study was carried out between October 2022 and April 2023. Participants were recruited via emails and online meetings with the Society for Learning and Instruction Informed by Evidence (S.Ap.I.E.) in the previous school year (2021-2022).

The intervention was delivered in bi-weekly sessions of approximately one and a half hours each, over 16-20 weeks (November 2022 - March 2023). Immediately before and after the intervention, pretest and posttest measures were administered to students in the intervention and comparison classes. Treatment teachers were provided with professional development by a member of the research team. Teachers received ten hours of initial training in three sessions to present the EIS model and its materials, as well as eight hours (four sessions) of ongoing support during the in-class implementation. Teachers were also provided with a guide to support their work during the implementation of the program and student's books for their classes. During the 16 to 20 weeks of EIS implementation in the treatment group, the comparison group continued with regular teaching practice. Since the intervention was delivered during regular mathematics classes, the comparison group benefited from the same amount of time of mathematics instruction as the EIS group.

3.6. *Analytic strategy*

3.6.1. Matching procedure and matching quality

Propensity score matching was applied to ensure balance between the two conditions and attenuate any selection bias (Rubin, 2001). Eleven classes willing to receive the intervention were matched to the same number of classes drawn from 73 classes in similar schools. We conducted one-to-one nearest neighbor matching at class level within the same grade level. We employed logistic regressions to predict a propensity score for each class, defined as the conditional probability of participating in the EIS intervention, given each class's value on the full set of covariates. Classes were matched on gender (proportion of females in each class) and pretest scores at class level for both measures used (i.e., General Math and SPM Test). We used the *MatchIt* package in R statistical software to conduct propensity score matching with the «nearest» method without replacement and using a caliper width of 0.25, to guarantee a close match in propensity scores between the groups (Ho *et al.*, 2011). We assessed the quality of the matching by calculating the standardized mean differences (SMDs) of the covariates between matched pairs at class and student levels. The SMDs were between the acceptable range of -0.25 and 0.25 (WWC, 2022), indicating balance between the two groups.

3.6.2. Quasi-experimental impact estimates

We employed an *Intention-To-Treat approach* (ITT), in which all students assigned to the conditions were included in the statistical analysis, whether they received the intervention or not. A two-level random intercept hierarchical linear model (HLM; Raudenbush & Bryk, 2002) was used to estimate treatment impact, accounting for the nested structure of the data (students nested in classes). Pretest, grade level and gender were used as covariates in the model improve precision.

We used the Bonferroni correction method to check for multiple comparisons. The *GAMLj* package (Gallucci, 2020) was used to estimate the models in the *Jamovi* statistical software (The Jamovi project, 2022). After estimating the models for the two outcome measures, we added the interaction between treatment and grade level to evaluate the potential moderating effect of grade level. Hedges' g was computed as the model-adjusted coefficient for treatment divided by the posttest unadjusted weighted pooled standard deviation.

4. Results

4.1. *Descriptive statistics and data screening*

Descriptive characteristics and pretest scores of the students in the EIS group and comparison group after attrition are shown in *Table 1*. As no classes left the study during the intervention, overall attrition (15.5%) and differential attrition (11.1%) at student level was due to missing data on pretest or posttest sessions. The final analytical sample included 22 classes and 278 students (*Fig. 1* for CONSORT Flow Diagram; Montgomery *et al.*, 2018).

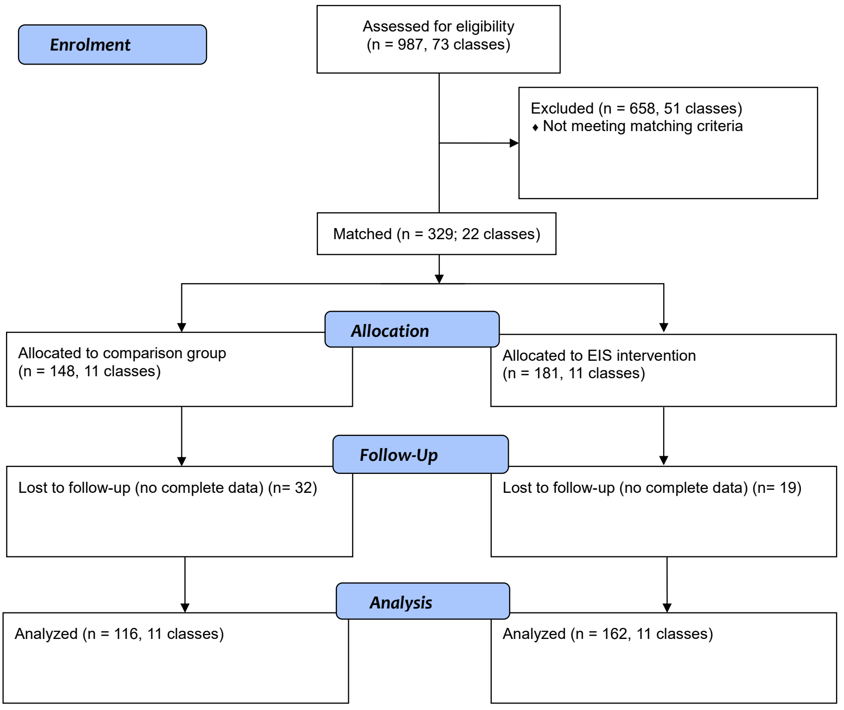

Figure 1. – CONSORT Flow Diagram.

Students in the two groups were similar in terms of demographic characteristics. SMDs for pretest measures were less than 0.25 SD for each measure, indicating baseline equivalence between the two groups, as required by What Works Clearinghouse (2022).

Online ISSN 2037-7924 - Print ISSN 2037-7932 - ISBN 978-88-5513-208-4

We screened the data for potential outliers, computing skewness and kurtosis statistics, and visually examined the box plots of pretest and post-test scores. Values of skewness and kurtosis were between the acceptable range of ±1.96 (Doane & Seward, 2011). Visual analysis of the box plots confirmed that there were no potential outliers.

4.2. *Impact estimates of EIS*

Students who received the EIS intervention obtained higher results on both outcome measures compared to the comparison group. However, these differences did not reach statistical significance. *Table 3* shows the results of the HLM analysis. The effect sizes ranged from 0.35 standard deviations for the SPM Test to 0.12 standard deviations for General Math.

Table 3. – Model estimates of the impact of EIS intervention checking for student covariates.

	General Math			SPM Test		
	ß (SE)	*95% CI [LL, UL]*	*p*	*ß (SE)*	*95% CI [LL, UL]*	*p*
Intercept	7.22 (0.52)	[6.20, 8.25]	< .001	48.48 (1.27)	[45.99, 50.98]	< .001
Treatment	0.45 (0.96)	[-1.44, 2.34]	.647	3.76 (2.34)	[-0.83, 8.35]	.125

Note: SE = Standard Error; CI = Confidence Interval; LL = Lower Level; UL = Upper Level. The models adjust for pretest scores, gender, and grade level. We applied a Bonferroni correction for models run separately for the two mathematics measures.

We explored the potential moderating effect of grade level on the impact of the EIS intervention on students' mathematics outcomes. There was no statistically significant interaction between treatment and grade level, showing a similar impact of EIS in third, fourth, and fifth grade (*Table 4*).

Table 4. – Descriptive Statistics by measure, group, and grade level at the posttest.

Outcome measure	Grade 3	Grade 4	Grade 5
	M (SD)	*M (SD)*	*M (SD)*
SPM			
EIS	46.5 (10.3)	49.5 (10.0)	55.8 (8.91)
Comparison	40.5 (6.41)	47.6 (11.4)	50.8 (9.97)
General Math			
EIS	7.99 (1.69)	8.07 (3.87)	6.54 (2.68)
Comparison	6.67 (2.39)	8.13 (3.87)	5.84 (3.12)

Note: M = Model-adjusted mean; SD = Unadjusted pooled standard deviation of the posttest.

5. Discussion

This quasi-experimental study investigated the efficacy of an intervention inspired by the Singapore math approach in Italy. This evaluation aimed to (i) explore the suitability of the Singapore math approach in the Italian primary school context, gauging student math performance; (ii) define the most appropriate methods and procedures for future large-scale evaluations. The discussion is organized around these two goals.

The current study represents the first step in the investigation of the efficacy and suitability of the Singapore math approach in the specific Italian context. Focusing on EIS efficacy, we found a non-significant effect ($g = 0.12$) on mathematics skills and on problem solving skills ($g = 0.35$). We expected that the findings would not reach statistical significance due to the small sample size in this initial evaluation. An interesting finding, although requiring further investigation, is the difference in effects between the two outcome measures. We would have expected a larger effect size on General Math compared to the SPM standardized measure. According to the literature, researcher-made measures are usually aligned with the intervention, which can lead to overestimation of their impact (Cheung & Slavin, 2016; Wolf & Harbatkin, 2023). One potential explanation is that, due to the substantial emphasis of EIS on problem solving skills, the SPM Test may have effectively gauged the influence on these specific skills, even though it was not explicitly designed for this evaluation. The preliminary evidence detected in this study is promising, and suggests the potential for further exploring the impact of EIS over an extended period, with a large-scale randomized trial. Further investigations are needed to better explore the difference in effects between the two types of outcome measures.

This study aimed to inform the design of future evaluations to study the effectiveness of the EIS intervention. The purpose of effectiveness studies is to offer evidence based on interventions conducted under typical conditions, with the goal of producing findings that can be applied to a broader population (Gertler *et al.*, 2016). Hence, future EIS effectiveness trials should address the limitations of the current work, related to the overall design, sample, and implementation. First, the design of effectiveness studies will require the use of random assignment with the prospectively trial registration, as it is considered the gold standard in impact evaluations (Slavin, 2008; Nutley *et al.*, 2013). While encouraged by the Consolidated Standards of Reporting Trials (CONSORT-SPI) Statement (Montgomery *et al.*, 2018), trail preregistration is still uncommon in social and educational research (Harrison & Mayo-Wilson, 2014). Second, the limited power of our sample has affected the conclusions of the current study. Future evaluations should involve a large sample with enough power to reach statistical significance. It is equally crucial to design studies with the ability to generalize the results to the population of interest (Tipton & Olsen, 2022). Finally, how the designed intervention is implemented is a central point in impact evaluations to make it replicable in regular school settings and to better inform the average treatment effect. Durlak and Dupre (2008) showed how implementation may affect the results, and concluded that the collection of such data is an essential feature of effectiveness evaluations. In our study we could not collect data on the number of lessons implemented by teachers, nor the adherence and quality of the intervention implementation. As part of future impact evaluations of the EIS intervention, we plan to design and conduct an implementation study to assess the degree to which an educational intervention is delivered as originally intended (i.e., implementation fidelity) and document the counterfactual, to measure the difference between the treatment and the control groups (Hill *et al.*, 2023).

6. Conclusions

This evaluation showed non-significant effects of EIS on students' mathematics skills, highlighting the need for further investigations. Future research should examine differential effects across student subgroups to identify which learners benefit most from the EIS approach and under what conditions. Most importantly, designing randomized evaluations with the ability to generalize the results to Italian schools are essential to comprehensively understand the impact of EIS and the conditions to maximize the effectiveness of the program.

Acknowledgement

The EIS evaluation was carried out as part of initiatives promoted by the Society for Learning and Instruction Informed by Evidence (S.Ap.I.E.). The authors would like to thank Cesare Fregola, Elena Ganzit, Aurora Mangiarotti, Rosangela Mapelli, Annarita Monaco, Alessandra Rastelli, Matteo Torre for their participation in the research group, as well as school principals and teachers who participated in the study.

Declaration of interest statement

The authors of the proposed manuscript are part of the developing team of the program evaluated.

References

Anthony, G., & Walshaw, M. (2009). Characteristics of effective teaching of mathematics: A view from the West. *Journal of Mathematics Education*, *2*(2), 147-164.

Bartolini Bussi, M.G., Sun, X., & Ramploud, A. (2013). A dialogue between cultures about task design for primary school. In C. Margolinas (Ed.), *Proceedings of ICMI Study 22: Task Design in Mathematics Education* (pp. 551-560). Oxford: ICMI.

Bruner, J.S. (1966). *Toward a Theory of Instruction*. Cambridge, MA: Belknap Press of Harvard University.

Chang, S.H., Lee, N.H., & Koay, P.L. (2017). Teaching and learning with concrete-pictorial-abstract sequence: A proposed model. *The Mathematics Educator*, *17*(1), 1-28.

Cheung, A.C., & Slavin, R.E. (2016). How methodological features affect effect sizes in education. *Educational Researcher*, *45*(5), 283-292.

Di Martino, V. (2015). Encouraging the success of foreign students in schools: Reinforcing problem solving in mathematics. In C. Coggi (Ed.), *Enhancing school success: The Fenix program* (pp. 159-185). Lecce: Pensa Multimedia.

Doane, D.P., & Seward, L.E. (2011). Measuring skewness: A forgotten statistic? *Journal of Statistics Education*, *19*(2). https://doi.org/10.1080/10691898.2011.11889611

Durlak, J.A., & Dupre, E.P. (2008). Implementation matters: A review of research on the influence of implementation on program outcomes and the factors affecting implementation. *American Journal of Community Psychology*, *41*(3-4), 327-350.

Educational Research Institute of America (2010). *A study of the Singapore Math Program, Math in Focus, state test results (Report 404)*. Boston, MA: Houghton Mifflin Harcourt.

Educational Research Institute of America (2013). *A study of the instructional effectiveness of Math in Focus (Report 466)*. Boston, MA: Houghton Mifflin Harcourt.

Gallucci, M. (2020). *GAMLj suite for Jamovi*. https://github.com/gamlj/gamlj

Gertler, P.J., Martinez, S., Premand, P., Rawlings, L.B., & Vermeersch, C.M. (2016). *Impact evaluation in practice*. Washington, DC: World Bank Publications. https://openknowledge.worldbank.org/handle/10986/25030

Harrison, B.A., & Mayo-Wilson, E. (2014). Trial registration: Understanding and preventing reporting bias in social work research. *Research on Social Work Practice*, *24*(3), 372-376.

Hedges, L.V., Tipton, E., Zejnullahi, R., & Diaz, K.G. (2023). Effect sizes in ANCOVA and difference-in-differences designs. *British Journal of Mathematical and Statistical Psychology*, *76*(2), 259-282.

Hill, C.J., Scher, L., Haimson, J., & Granito, K. (2023). *Conducting implementation research in impact studies of education interventions: A guide for researchers (NCEE 2023-005)*. Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance (NCEE).
http://ies.ed.gov/ncee

Ho, D.E., Imai, K., King, G., & Stuart, E.A. (2011). MatchIt: Nonparametric preprocessing for parametric causal inference. *Journal of Statistical Software*, *42*(8).
https://doi.org/10.18637/jss.v042.i08

INVALSI (2024). *Rapporto INVALSI 2024*.

Jaciw, A.P., Hegseth, W.M., Lin, L., Toby, M., Newman, D., Ma, B., & Zacamy, J. (2016). Assessing impacts of Math in Focus, a «Singapore Math» program. *Journal of Research on Educational Effectiveness*, *9*(4), 473-502.
https://doi.org/10.1080/19345747.2016.1164777

Jerrim, J., & Vignoles, A. (2016). The link between East Asian «mastery» teaching methods and English children's mathematics skills. *Economics of Education Review*, *50*, 29-44.
https://doi.org/10.1016/j.econedurev.2015.11.003

Kapur, M. (2016). Examining productive failure, productive success, unproductive failure, and unproductive success in learning. *Educational Psychologist*, *51*(2), 289-299.
https://doi.org/10.1080/00461520.2016.1155457

Kaur, B. (2019). The why, what and how of the «Model» method: A tool for representing and visualising relationships when solving whole number arithmetic word problems. *ZDM Mathematics Education*, *51*(1), 151-168.
https://doi.org/10.1007/s11858-018-1000-y

Kaur, B. (2021). A look at Singapore mathematics education through the PISA and TIMSS lenses. In *Singapore Math and science education innovation* (pp. 61-73). Singapore: Springer.

Lee, N.H., Lee, J., & Wong, Z.Y. (2021). Preparing students for the fourth industrial revolution through mathematical learning: The constructivist learning design. *Journal of Educational Research in Mathematics*, *31*(3), 321-356.
https://doi.org/10.29275/jerm.2021.31.3.321

Lee, N.H., Seto, C., Rahim, R., & Soon, T. (Eds.). (2020). *Mathematics teaching in Singapore*, Vol. 1: *Theory-informed practices*. Singapore: Word Scientific.

Lindorff, A.M., Hall, J., & Sammons, P. (2019). Investigating a Singapore-based mathematics textbook and teaching approach in classrooms in England. *Frontiers in Education*, *4*, art. 37. https://doi.org/10.3389/feduc.2019.00037

Lucangeli, D., Tressoldi, P.E., & Cendron, M. (2003). *Test SPM – Abilità di soluzione dei problemi matematici. Abilità di soluzione dei problemi matematici*. Trento: Erickson.

Montgomery, P., Grant, S., Mayo-Wilson, E., Macdonald, G., Michie, S., Hopewell, S., & Moher, D.; on behalf of the CONSORT-SPI Group (2018). Reporting randomised trials of social and psychological interventions: the CONSORT-SPI 2018 extension. *Trials*, *19*, 407.

Mullis, I.V.S., Martin, M.O., Foy, P., Kelly, D.L., & Fishbein, B. (2020). *TIMSS 2019 international results in mathematics and science*. Boston College, MA: TIMSS & PIRLS International Study Center. https://timssandpirls.bc.edu/timss2019/international-results/

Ng, S.F., & Lee, K. (2009). The model method: Singapore children's tool for representing and solving algebraic word problems. *Journal for Research in Mathematics Education*, *40*(3), 282-313.

Nutley, S.M., Powell, A.E., & Davies, H.T.O. (2013). *What counts as good evidence*. London: Alliance for Useful Evidence. http://hdl.handle.net/10023/3518

OECD – Organisation for Economic Co-operation and Development (2023). *PISA 2022 results*, Vol. 1: *The state of learning and equity in education*. Paris: OECD Publishing. https://doi.org/10.1787/53f23881-en

Pellegrini, M., Lake, C., Neitzel, A., & Slavin, R.E. (2021). Effective programs in elementary mathematics: A meta-analysis. *AERA Open*, *7*. https://doi.org/10.1177/233285842098621

Porta, M. (2008). *A dictionary of epidemiology* (5th ed.). New York: Oxford University Press.

Purwadi, I., Sudiarta, I., & Suparta, I.N. (2019). The effect of concrete-pictorial-abstract strategy toward students' mathematical conceptual understanding and mathematical representation on fractions. *International Journal of Instruction*, *12*(1), 1113-1126.

Raudenbush, S.W., & Bryk, A.S. (2002). *Hierarchical linear models: Applications and data analysis methods*, Vol. 1. Newbury Park, CA: Sage.

Rubin, D.B. (2001). Using propensity scores to help design observational studies: Application to the tobacco litigation. *Health Services and Outcomes Research Methodology*, *2*(3-4), 169-188. https://doi.org/10.1023/A:1020363010465

Salingay, N., & Tan, D. (2018). Concrete-Pictorial-Abstract approach on students' attitude and performance in mathematics. *International Journal of Scientific & Technology Research*, *7*(5), 90-111.

Schoenfeld, A.H. (2016). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. *Journal of Education*, *196*(2), 1-38. https://doi.org/10.1177/002205741619600202

Shadish, W.R., Cook, T.D., & Campbell, D.T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston, MA: Houghton, Mifflin and Company.

Singapore Ministry of Education (2006). *Mathematics Syllabus Primary*. https://libris.nie.edu.sg/sites/default/files/math2007a.pdf

Slavin, R.E. (2008). Response to comments. Evidence-based reform in education: Which evidence counts? *Educational Researcher*, *37*(1), 47-50.

Spagnolo, F., & Di Paola, B. (2010). *European and Chinese cognitive styles and their impact on teaching mathematics*. Berlin: Springer.

The Jamovi project (2022). *Jamovi* (version 2.3). https://www.jamovi.org

Tipton, E., & Olsen, R.B. (2022). *Enhancing the generalizability of impact studies in education (NCEE 2022-003)*. Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance (NCEE). http://ies.ed.gov/ncee

Toh, T.L., Chan, C.M.E., Tay, E.G., Leong, Y.H., Quek, K.S., Toh, P.C., …, & Dong, F. (2019). Problem solving in the Singapore school mathematics curriculum. In T.L. Toh, B. Kaur, & E.G. Tay (Eds.), *Mathematics education in Singapore* (pp. 141-164). Berlin: Springer.

What Works Clearinghouse (2022). *What Works Clearinghouse procedures and standards handbook, version 5.0.* U.S. Washington, DC: Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance (NCEE). https://ies.ed.gov/ncee/wwc/Handbooks

Wolf, B., & Harbatkin, E. (2023). Making sense of effect sizes: Systematic differences in intervention effect sizes by outcome measure type. *Journal of Research on Educational Effectiveness*, *16*(1), 134-161.

Zan, R. (2011). The crucial role of narrative thought in understanding story problems. *Current State of Research on Mathematical Beliefs*, *XVI*, 287-305.

Zan, R. (2016). *I problemi di matematica. Difficoltà di comprensione e formulazione del testo*. Roma: Carocci.

Riassunto

EIS (Enattivo, Iconico, Simbolico) è un programma recentemente sviluppato che si ispira alle metodologie didattiche utilizzate nell'approccio matematico di Singapore. L'intervento enfatizza il dominio sequenziale dei concetti matematici, la risoluzione di problemi e l'uso dell'approccio Concrete to Pictorial to Abstract (CPA). Il presente studio quasi-sperimentale valuta l'impatto del programma EIS sulle performance matematiche degli studenti per esplorare l'applicabilità dell'approccio di Singapore nel contesto italiano e definire i metodi più appropriati per future valutazioni su larga scala. Undici classi sperimentali dalla terza alla quinta elementare sono state abbinate con 11 classi di controllo tramite la tecnica del «propensity score matching». Le performance matematiche sono state misurate prima e dopo implementazione dell'intervento. Le analisi per stimare l'effetto del trattamento sono state condotte tramite un modello multi-livello. Dopo l'implementazione di EIS per 16-20 settimane non sono stati riscontrati effetti statisticamente significativi. I risultati, con valori di effect size fra 0.12 e 0.35, suggeriscono la necessità di ulteriori indagini tramite valutazioni su larga scala.

Parole chiave: Abilità matematiche; Disegno quasi-sperimentale; Metodo Singapore; Scuola primaria.

How to cite this paper: Pellegrini, M., Di Martino, V., & Trinchero, R. (2025). Effects of the *Enactive, Iconic, Symbolic* (EIS) intervention on student math skills in primary school [Effetti del programma *Enattivo, Iconico, Simbolico* (EIS) sulle competenze matematiche degli studenti nella scuola primaria]. *Journal of Educational, Cultural and Psychological Studies (ECPS)*, *31*, 71-89. https://doi.org/10.7358/ecps-2025-031-pell