Unilasallista Corporación Universitaria
Editorial Lasallista
Revista Lasallista -de Investigación-

Artículo original / Original article / Artigo original
DOI: https://doi.org/10.22507/rli.v22n1a3663

Enhancing Learning for 7-10-Year-Olds through Functional Advanced Didactics: A Promising Approach in Colombia[1]

Santolo Ciccarelli[2], Francesco V. Ferraro[3], Karol Gutiérrez-Ruiz[4], William Arellano-Cartagena[5], Kiara Campo Landines[6], María Luisa Iavarone[7]

Abstract

Introduction: This study introduces the Functional Advanced Didactics (FAD) method, a novel multidisciplinary pedagogical approach based on the theory of embodied cognition and gamification, which integrates physical activity with conventional school subjects. **Objective:** This study aimed to explore the potential of this innovative method to enhance student learning and cognitive abilities. **Materials and Methods:** A pilot study was conducted with 60 students (26 boys and 34 girls) aged 7 – 10 years from a public school in Cartagena (Colombia). A pretest–posttest design was employed to explore the potential effects of the FAD method on learning and cognition. The intervention was implemented in lieu of conventional teaching methods for a period of 13 consecutive weeks in mathematics, English, geometry, history, and geography. The intervention outcomes were assessed through the administration of learning and neuropsychological tests. **Results:** This pilot study demonstrated that FAD administration resulted in improvements in English and mathematics learning, as well as enhancements in cognitive processes, including verbal and visual memory, visuospatial skills, and the ability to plan and solve problems. **Conclusions:** Preliminary

1 Original article derived from the Functional Advanced Didactics (FAD) research project executed between May 2022 and May 2023 in Cartagena, Colombia; Research groups Education and Educational Innovation, and Development, Health and Human Performance of the Universidad Tecnológica de Bolívar. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

2 Università degli Studi di Napoli Parthenope (Italy). E-Mail: santolo.ciccarelli001@studenti.uniparthenope.it, ORCID: 0000-0002-5660-1310. Corresponding author.

3 Clinical Exercise and Rehabilitation Research Centre, University of Derby (England). E-Mail: f.ferraro@derby.ac.uk, Orcid: 0000-0002-4902-7760.

4 PhD in Neuropsychology, Psychologist, Associate Professor and member of the Development, Health and Human Performance research group, Universidad Tecnológica de Bolívar (Colombia). E-Mail: kgutierrez@utb.edu.co, ORCID: 0000-0002-6808-9086.

5 PhD in Education Sciences, Master in Education, Economist. Dean of the Faculty of Education and member of the Education and Educational Innovation research group, Universidad Tecnológica de Bolívar (Colombia). E-Mail: warellano@utb.edu.co, ORCID: 0000-0003-3523-5718.

6 Master in Psychology, Psychologist, member of the Development, Health and Human Performance research group, Universidad Tecnológica de Bolívar (Colombia). E-Mail: kcampo@utb.edu.co, ORCID: 0000-0003-1428-1483.

7 Full professor of General and Social Education in the Department of Motor Science and Wellness at the Università degli Studi di Napoli Parthenope (Italy). E-Mail: marialuisa.iavarone@uniparthenope.it, ORCID: 0000-0002-9246-2696.

Autor para Correspondencia: santolo.ciccarelli001@studenti.uniparthenope.it

Recibido: 12/07/2024 Aceptado: 25/06/2025

*Los autores declaran que no tienen conflicto de interés

evidence suggests that FAD may have the potential to enhance learning and cognitive abilities. Nevertheless, further research is required to fully elucidate the impact of FAD on learning and cognitive processes.

***Keywords*:** Embodied cognition, cognitive functions, gamification, learning, motor activity.

Potenciando el aprendizaje de los niños de 7 a 10 años mediante la enseñanza funcional avanzada: un enfoque prometedor en Colombia

Resumen

Introducción: este estudio presenta el método enseñanza funcional avanzada (EFA), un novedoso enfoque pedagógico multidisciplinar basado en la teoría de la cognición corporizada y la gamificación, que integra la actividad física con las asignaturas escolares convencionales. **Objetivo:** este estudio pretende explorar el potencial de este innovador método para mejorar el aprendizaje y las habilidades cognitivas de los estudiantes. **Materiales y métodos:** se realizó un estudio piloto con 60 estudiantes (26 niños y 34 niñas) de 7 a 10 años de una escuela pública de Cartagena (Colombia). Se empleó un diseño pretest-postest para explorar los efectos potenciales del método EFA sobre el aprendizaje y la cognición. La intervención se implementó en lugar de los métodos de enseñanza convencionales durante un periodo de 13 semanas consecutivas en las asignaturas matemáticas, inglés, geometría, historia y geografía. Los resultados de la intervención se evaluaron mediante la aplicación de pruebas de aprendizaje y neuropsicológicas. **Resultados:** este estudio piloto demostró que la administración de la EFA produjo mejoras en el aprendizaje de inglés y matemáticas, así como mejoras en procesos cognitivos como la memoria verbal y visual, las habilidades visoespaciales y la capacidad para planificar y resolver problemas. **Conclusiones:** este estudio piloto sugiere que el método EFA puede tener el potencial de mejorar el aprendizaje y las capacidades cognitivas. No obstante, es necesario seguir investigando para dilucidar plenamente el impacto de la EFA en el aprendizaje y los procesos cognitivos.

***Palabras clave*:** cognición corporizada, funciones cognitivas, gamificación, aprendizaje, actividad física.

Melhorar a aprendizagem das crianças de 7-10 anos através da Didática Funcional Avançada: Uma abordagem promissora na Colômbia

Resumo

Introdução: Este estudo apresenta o método da Didática Avançada Funcional (DAF), uma nova abordagem pedagógica multidisciplinar baseada na teoria da cognição incorporada e da gamificação, que integra a atividade física com as disciplinas escolares convencionais. **Objetivo:** Este estudo teve como objetivo explorar o potencial deste método inovador para melhorar a aprendizagem e as capacidades cognitivas dos alunos. **Materiais e Métodos:** Foi realizado um estudo piloto com 60 alunos (26 rapazes e 34 raparigas) com idades entre os 7 e os 10 anos de uma escola pública de Cartagena (Colômbia). Foi utilizado um desenho pré-teste-pós-teste para explorar os efeitos potenciais do método DAF na aprendizagem e na cognição. A intervenção foi implementada em vez dos métodos de ensino convencionais durante um período de 13 semanas consecutivas em matemática, inglês, geometria, história e geografia. Os resultados da intervenção foram avaliados através da administração de testes de aprendizagem e neuropsicológicos. **Resultados:** Este estudo piloto demonstrou que a administração do DAF resultou em melhorias na aprendizagem do inglês e da matemática, bem como em melhorias nos processos cognitivos, incluindo a memória verbal e visual, as competências visuoespaciais e a capacidade de planear e resolver problemas. **Conclusões:** Os dados preliminares sugerem que o FAD pode ter o potencial de melhorar a aprendizagem e as capacidades cognitivas. No entanto, é necessária mais investigação.

***Palavras-chave*:** Cognição incorporada, funções cognitivas, gamificação, aprendizagem, atividade motora.

Introduction

The quality of public education in Colombia is an urgent challenge. As evidenced by the OECD's PISA results, there is a notable deficiency in academic performance when compared to other states. This is attributed to the absence of a unified curriculum and the suboptimal functioning of the educational system (Carroll et al., 2020). In the Colombian Caribbean region, characterized by low socioeconomic levels and rural areas, students from low socioeconomic backgrounds exhibited diminished cognitive performance, indicating deficiencies in the quality of education (Education Observatory of the Colombian Caribbean, 2023). To reverse this trend, policies must be implemented that enhance learning. These policies should be enacted through educational institutions, as they offer an opportunity to improve cognitive skills (Macedonia and Repetto, 2017).

In the field of contemporary education, there is a growing interest in innovative pedagogical approaches that merge physical elements and cognitive stimuli to improve learning and facilitate student neurodevelopment (Deng et al., 2023; Gallagher, 2023; Smith, 2023). Educational methods based on the principles of embodied cognition theory posit that knowledge is shaped by physical experience and sensory-motor engagement rather than by abstract symbols or exclusively mental representations (Tanton, 2023). These methods have been demonstrated to be effective in improving

cognitive abilities and in the acquisition of concepts and notions (Feng, 2023; Srinivasa et al., 2022). This shift towards embodied pedagogy acknowledges the role of the body as a metronome in educational processes. The dynamic relationship between the organism and the surrounding environment enables the body to enrich teaching practices (Sibilio and Galdieri, 2022; Chettaoui et al., 2022).

Similarly, the adoption of gamification methodology, which integrates game design techniques in structured contexts such as school environments (Alvarado and Rosado, 2023; Seiffert-Brockmann and Neureiter, 2023), is a valuable tool for improving teaching experience. This is evidenced by the fact that it leads students to higher levels of participation and the preservation of knowledge (Ali et al., 2023). In addition to promoting cognitive aspects such as attention, memory, executive functions, processing speed, motor coordination, and movement (Luarn et al., 2023), it should be noted that this approach is integrated with teaching disciplines based on the use of the body, such as physical education (Becerra-Fernández, 2022).

Several studies have indicated that the implementation of multidisciplinary teaching protocols that integrate physical education with other subjects can result in positive learning outcomes (Doherty and Forés Miravalles, 2019; Vetter et al., 2020). Concurrently, other studies have demonstrated that the conjunction of school subjects that share skills or competencies can facilitate their comprehension when associated with one another (Freeth and Caniglia, 2020). A clear illustration of this profound interconnection can be observed when physical education and science are considered. In both subjects, the concept of force is a fundamental element. Similarly, the sequence element is present in a variety of disciplines, including grammar, history, mathematics, music, and once again, physical education. These disciplines all adhere to a linear logic with progressive patterns (Nicolosi et al., 2017).

A growing body of research indicates a correlation between physical activity and mathematical performance among early school-aged children. For instance, the *Eduball* teaching method was developed utilizing educational balls imprinted with letters, numbers, and symbols to facilitate team mini games. This approach has been demonstrated to yield significant improvements in mathematics performance (Cichy et al., 2020) and English language proficiency (Cichy et al., 2022). In a study conducted in Italy by Boat et al. (2022), a teaching protocol was proposed that included physically active lessons focused on mathematics and the study of the English language for 8 hours a week over a duration of 16 weeks. The study involved 192 children, of whom 98 were part of the experimental group and 94 were part of the control group. The results demonstrated that, in comparison to the control group, the intervention group exhibited significantly enhanced improvements in all domains of cognitive function assessed as well as in the overall score and sub-scales (locomotive and object control skills) of the gross motor skills test.

Accordingly, a multidisciplinary teaching approach based on gamification that considers physical exercise integrated with other academic subjects can facilitate coherent and fluid teaching, enabling students to comprehend concepts more effectively and apply them in diverse contexts (Sotos-Martínez et al., 2023). Such synergy can be a valuable opportunity to promote deeper and more meaningful learning, resulting in enhanced neurocognitive development (Bidzan-Bluma and Lipowska, 2018).

In this regard, the research team has developed the method FAD, which integrates conventional teaching through the use of movement-related materials and equipment,

including gymnastics tools that are common to all schools, as well as teaching subsidies such as office materials. The objective of the protocols with motor activity is to promote multidisciplinary learning among children in primary school. The aim is to transfer all those concepts and notions belonging to conventional school subjects from the classroom to the gymnasium of the school (Latino et al., 2020). The research team hypothesizes that this method can facilitate the acquisition of concepts and notions pertinent to the specific school subjects while also enhancing cognitive abilities through play and motor activities.

Materials and Methods

Design

This prospective study employed a one-group, pretest–posttest design to investigate the potential efficacy of the FAD method in enhancing the assimilation of concepts and notions associated with school learning and cognitive processes in primary school students from a public school. The objective of this study was to conduct an initial exploration trial, the findings of which will serve as a basis for future randomized controlled trials.

Sample

A third-grade classroom at the Mercedes Abrego Educational Institution, situated in the Colombian city of Cartagena, was selected for inclusion in the study. The school is a public institution that serves students from low socioeconomic backgrounds. The study included 60 students (26 boys and 34 girls) aged 7–10 years. The inclusion criteria for the sample were as follows: the participants were required to be in their third year of primary school, to be native Spanish speakers, and to have an estimated full-scale IQ of 80 or above. This was established using a short version of the Wechsler Intelligence Scale for Children–Revised (WISC-R; Wechsler et al., 1993) (Sattler & Hoge 2006). Individuals with neurodevelopmental disorders, including autism spectrum disorder, attention-deficit/hyperactivity disorder, specific learning disorder, and/or movement disorders, were excluded from the analysis. The participants were recruited over a period of five months, from 1 May 2022 to 30 September 2022.

Measures

Learning measures. The learning measures employed in this study consisted of five questionnaires developed by the research team in collaboration with the teachers involved in the project. These questionnaires were designed to assess the concepts and notions of mathematics (calculation skills), English (word-picture association to measure the learning of new vocabulary and color recognition), geometry (recognition of geometric shapes), history, and geography typical of the third grade. The number of correct answers obtained from each questionnaire was estimated.

Neuropsychological measures. The Neuropsychological Assessment Battery for Children (Matute et al., 2013) was employed in the present study. This battery of tests assesses the cognitive abilities of Spanish-speaking children aged 5 – 16 years. The administered tests encompassed domains such as auditory memory, encoding and delayed recall processes, and the organization and planning subtest (Pyramid of Mexico). The scores obtained from the tests were expressed in terms of percentiles. The test-retest reliability for these tasks falls between 0.59 and 0.68. Furthermore, the Rey-Osterrieth Complex Figure Test (Rey-Osterrieth, 1997) was employed. This test assesses perceptual organization, visual memory and visual constructional ability. Normative data for this test are available for children in Colombia

aged between 6 and 17 years. The instrument demonstrates satisfactory reliability, with a Cronbach's alpha coefficient of 0.77 for figure copying and 0.66 for figure recovery. Percentiles were used to express the scores obtained from the tests (Arango-Lasprilla et al., 2017).

Intervention

The FAD methodology was implemented in lieu of conventional teaching methods for a period of 13 weeks, with a two-week intermission at the outset of the intervention due to the Colombian government's provision of holidays, totaling 15 weeks. The ratio of teachers to learners was 1:10, with two instructors present in this study. The following section outlines the various stages of the intervention.

Each session lasted approximately two hours and was comprised of three distinct phases. The initial phase of the session consisted of a ten-minute *warm-up activity* designed to stimulate learners' cognitive and motor skills. This phase entailed the execution of imagined motor schemes with the objective of enhancing laterality and attention. As the lesson progressed, one instructor provided verbal cues at three distinct speeds, indicated by "Green" (maximum speed), "Yellow" (medium speed), and "Red" (stop). Subsequently, the *nuclear phase* commenced, which, contingent upon the specific discipline being imparted, entailed motor circuits or game activities. These activities, in addition to conventional gymnastic apparatus, incorporated teaching aids and stationery items such as cards, tape, blackboards, and markers. Prior to commencing this phase, the instructor provided the students with an explanation of the rules to be followed and the tasks to be performed, demonstrating these through practical examples. **Figure 1** provides an illustrative example of an activity designed to facilitate English language learning.

Figure 1.

Example of an activity designed to facilitate English language learning

Source. Prepared by authors.

The instructor-maintained order and concentration within the group through the use of short, playful activities called *Distractors*. These activities, related to the specific subject matter, were carried out at high intensity and used both during group and individual activities to stimulate active participation from each student. Furthermore, *Distractors* were employed when a second instructor oversaw the subsequent motor circuit and game activities.

At the conclusion of each learning unit, a brief debriefing was conducted to ascertain the comprehension of the concepts presented and to address any remaining questions. At the end of the session, a *retrospective phase* was implemented to mitigate fatigue. This phase consisted of a brief educational activity on emotional regulation, lasting 10 minutes. This activity involved comparison, dialogue, and the recognition of specific emotions, with the objective of promoting understanding and acceptance of emotions.

Procedure

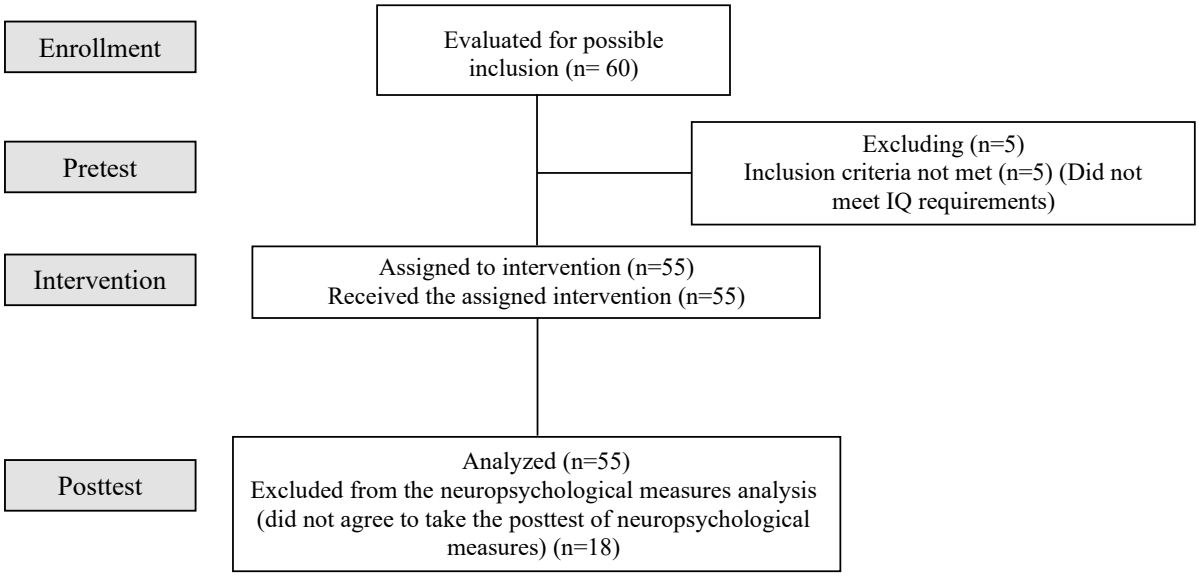
The study was conducted in four phases:1) the selection of participants, 2) a pretest assessment to establish a baseline, 3) the intervention, and 4) a posttest assessment. Before participation, participants provided written informed consent.

In the first phase of the study, the children were initially assessed using the abbreviated version of the WISC-R (Wechsler et al., 1993), and the parents completed a health history questionnaire. Children who met the established criteria were included in the study. In the second phase of the study, the baseline for the research was established (pretest). Children were evaluated using learning questionnaires and neuropsychological measures. In the third phase of the study, the FAD method was employed. Finally, in the fourth phase, a posttest evaluation was conducted at the conclusion of the intervention period, using the same instruments that were administered for the baseline. The posttest assessment was conducted, on average, six weeks after the conclusion of the intervention.

A total of 60 children were initially recruited for the study, of whom 55 met the established inclusion criteria. Five children did not meet the criterion for an estimated full-scale IQ of 80 or above (three boys and two girls). Additionally, 18 children did not consent to undergo the posttest of neuropsychological measures. Consequently, the children's scores were excluded from the subsequent analyses of the neuropsychological measures (see **Figure 2**). All phases of the study were conducted by an expert with a bachelor's degree in Motor Sciences. All participants attended a minimum of 12 out of 15 lessons. The authors confirm that all procedures were conducted in accordance with the ethical standards set forth by the relevant national and institutional committees governing human experimentation. The parents or legal guardians of the participants provided informed consent, and the data were anonymized and collected in accordance with the guidelines set forth in the 1975 Declaration of Helsinki, as revised in 2013.

Figure 2.

Flow chart on the sequence of phases of the study (enrollment, intervention assignment, and data analysis)



Source. Prepared by authors.

Data analysis

Data analysis was performed using the SPSS version 27. Descriptive statistics were calculated for all variables. Based on the results from the Shapiro-Wilk normality test, the non-parametric Wilcoxon test was used for data that did not follow a normal distribution, whereas the parametric Student's t-test was used for data that did follow a normal distribution. Further analysis was conducted to determine whether the gender of the participants influenced the scores obtained on the learning and neuropsychological tests, as previous studies have reported that gender can influence students' behavior and attitudes (Chapman et al., 2018; Dhar et al., 2018).

A 2 × 2 repeated-measures analysis of variance (ANOVA) was performed, with two factors: gender (male and female) and evaluation time (pretest and posttest). The dependent variables were the scores on the learning and neuropsychological tests, as previously described. The gender × time interaction effects and main effects were estimated separately for each dependent variable. Pairwise comparisons were performed for the main and interaction effects using post-hoc analyses with Bonferroni adjustment. The observed effect size and power for all estimates were calculated.

Results

Table 1 presents the primary descriptive data for the participants' baseline learning scores and posttest results. The results indicated that participants exhibited significantly lower scores on mathematics ($t(54) = -2.70$, $p < .01$, $d = -0.35$) and English image-word relations tests ($Z = -3.85$, $p < .01$, $r = -0.35$) prior to the implementation of the FAD

method compared to the post-implementation period, with a medium effect size. For the remaining measures, no statistically significant differences were found between the pretest and posttest.

Table 1.

Learning questionnaire scores

Learning variables	Pretest	Posttest	*p* Value	Effect size	1-ß
Mathematics	3.98 ± 0.37	4.61 ± 1.96	0.009	-0.35	0.96
English image-word relations	7.38±3.88	10.83±3.74	0.000	-0.35	0.95
English colours	4.95 ± 1.37	5.20 ± 2.86	0.394	-0.07	0.11
Form recognition geometry	5.73 ± 2.70	6.15 ± 31.56	0.479	-0.05	0.08
Geography	4.17 ± 2.23	4.12 ± 2.64	0.851	-0.02	0.05
History	4.58 ± 2.07	5.15 ± 2.62	0.156	-0.13	0.29

Note: Data are reported as mean ± standard deviation; p-value refers to the significance index; 1-ß: statistical power.

***Source*.** Prepared by authors.

Table 2 presents the main descriptive data for the participants' baseline neuropsychological scores and posttest scores. It was found that participants had significantly lower scores in copying (Z = -1.95, p = .05, r = -0.21) and recovery (t(31) = -2.42, p < .05, d = -0.43) of the Rey-Osterrieth complex figure, in the encoding of verbal information (Z = -3.19, p < .01, r = -0.35), in long-term cue retrieval (Z = -3.19, p < .01, r =–0.49), and in the number of movements in the Pyramid of Mexico test (t(37) = -1.99, p = .05, d = -0.32) before the implementation of the FAD method compared to after, with effect sizes ranging from small to medium. For the remaining neuropsychological measures, no statistically significant differences were found between the pretest and posttest.

Table 2.

Standardized neuropsychological scores

Tests	Pretest	Posttest	*p* Value	Effect size	1-ß
Copy Rey-Osterrieth complex figure	43.88 ± 33.69	56.25 ± 33.16	0.051	-0.21	0.60
Recovering Rey-Osterrieth complex figure	51.88 ± 29.23	63.28 ± 27.35	0.022	-0.43	0.99
Word list coding	20.53 ± 29.09	41.25 ± 34.40	0.001	-0.35	0.96
Memory of a story	31.71 ± 26.10	37.43 ± 32.02	0.441	-0.08	0.14
Deferred evocation word list	39.23 ± 32.43	48.53 ± 30.12	0.175	-0.23	0.71
Recovering history	30.16 ± 25.61	37.90 ± 33.01	0.265	-0.12	0.25
Key recovery of the word list	32.69 ± 26.69	50.91 ± 30.61	0.004	-0.49	0.99
Word list recognition	1.44 ± 5.58	1.42 ± 7.88	0.892	-0.02	0.05
Number of movements Pyramid of Mexico	37.48±29.69	49.82±28.08	0.050	-0.32	0.94

Note: Data are reported as mean ± standard deviation; p-value refers to the significance index; 1-ß: statistical power.

Source. Prepared by authors.

An analysis of the data, including the gender variable as an intersubject factor, was performed in a repeated measures analysis of variance (ANOVA) to determine whether the gender of the participants influenced the pre- and posttest scores during the implementation of the FAD method. A significant interaction between gender and time was found ($F(1, 54) = 10.44$, $p < .01$, $np^2 = 0.15$) on the geometric shape recognition test. Males ($M = 7.35$, $SE = 0.58$) scored significantly higher than females ($M = 5.24$, $SE = 0.51$, $t(22) = -2.74$, $p < .01$, $d = -0.53$) on the posttest, with a moderate effect size, whereas gender did not influence the other learning measures. There was no interaction effect of gender and time on neuropsychological scores ($p > .05$).

Discussion

The findings of this study indicated that the implementation of the FAD method resulted in significant improvements in various domains. Notably, the results demonstrate enhanced learning outcomes in the context of English language acquisition and mathematical comprehension. Furthermore, the investigation revealed notable enhancements in cognitive processes, including verbal and visual memory, as well as improvements in visuospatial skills and the ability to plan and organize behaviors when tackling complex problem-solving tasks, irrespective of the gender of the participants. These findings highlight the potential of FAD as a valuable tool for enhancing both learning and cognitive abilities, with promising implications for educational practices and cognitive development strategies.

Previous studies have investigated the efficacy of exercises designed for implementation in primary schools for teaching English and mathematics disciplines. For example, a study protocol described by Mavilidi et al. (2019) extends the *Thinking While Moving in Math* intervention to English lessons in primary schools. The program demonstrated the potential to enhance the physical activity levels and academic outcomes of primary school children. Another study conducted in Australia on a sample of 172 children in their third year of primary school employed a protocol comprising a 10-minute shuttle run, a 5-minute circuit, 10-minute pair relays utilizing game tools such as dominoes, tables with numbers and worksheets, and a 5-minute 'booster' game with the ball. The results demonstrated a more pronounced improvement in the experimental group's performance in multiplication tables than in the control group's performance in usual classroom activities (Vetter et al., 2019). It can be reasonably inferred that integrating physical activity into mathematics and English classes will ensure that children are more active and can have positive effects on both physical and cognitive outcomes. It is evident that students derive pleasure from physical movement. Previous research has indicated a correlation between physical activity and enhanced learning outcomes (Shapiro, 2019). Our findings corroborate this conclusion.

It seems reasonable to suggest that educators should consider incorporating games that involve physical and playful activities into the curriculum of mathematical and English education. Spontaneous play can naturally incorporate mathematical concepts, enabling young children to explore numbers as they engage in play. Play provides children with the opportunity to acquire vocabulary, grasp fundamental concepts, tackle problems, nurture their memory and creativity, develop language skills and serves as a platform to develop mathematical abilities (Cichy et al., 2020). Therefore, play provides an encouraging foundation for the teaching of mathematics and languages. Further research, employing experimental methodologies is necessary to substantiate these findings in the target population.

The pilot study demonstrated that certain cognitive abilities, including verbal and visual memory, visuospatial skills, and executive functions such as organization and planning, could also be enhanced following the implementation of the FAD method. Consistent with our findings, previous research has indicated that environments that encourage physical activity can positively influence children's cognitive function (Kolovelonis et al., 2022).

This study is subject to several limitations pertaining to the threats to internal and external validity inherent to the one-group pretest–posttest pre-experimental design. The random assignment to the treatment and control groups was challenging to implement in this study due to practical constraints related to the limited resources and infrastructure available for the FAD method at the participating educational institution. Consequently, we view the use of this design as a preliminary effort for a future, larger-scale study. Other limitations include the brief duration of the intervention, the reduced number of participants, and the timing of the intervention during school holidays. The challenging context in which the FAD was selected for testing, coupled with the destitute circumstances of some students who frequently arrived at class malnourished, dehydrated, and inadequately clothed for a playful motor activity, posed significant obstacles to the study.

There is a clear need for further comprehensive research into the effects of the FAD method on children's learning and cognitive development. Such research should encompass a broader range of participants,

including individuals from different age groups and socioeconomic backgrounds, and should incorporate experimental methodologies along with skill assessments.

Conclusions

The Functional Advanced Didactics (FAD) approach appears to be a promising method, as the study conducted by the research team yielded encouraging results in the areas of English language learning and mathematics in a group of primary school students from a public school in Cartagena, Colombia. Furthermore, the FAD method demonstrated its ability to facilitate specific cognitive processes. Nevertheless, further research is required to more accurately assess the impact of the FAD method on learning and cognitive abilities.

This pilot's study offers preliminary evidence that integrating physical activity with other educational disciplines is feasible in educational contexts with limited economic resources. Moreover, the findings indicate that such integration has the potential to enhance learning outcomes in subjects such as English and mathematics. An embodied-centered approach may prove to be an effective strategy for achieving a balance between playful aspects and structured teaching, thereby optimizing learner motivation.

Conflict of Interest declaration

The authors certify that they have no affiliations with, nor are they involved in, any organization or entity with a financial interest in the subject matter or materials discussed in this manuscript.

Author Contributions: SC, KG, WA, ML, and KC were instrumental in the design and implementation of the research. FF and KG were responsible for the analysis of the results, all authors were involved in the writing of the manuscript. SC and FF were responsible for conceiving the original concept and for supervising the project.

References

Ali, K., Sawalha, A., Abd-Rabo, A. M. and Hashaykeh, S. (2023). Role of Digital Games and Gamification in Promoting the Learning Process. In Z. Khlaif, M. Sanmugam and J. Itmazi (Eds.), *Advances in Mobile and Distance Learning* (pp. 256-262). IGI Global. https://doi.org/10.4018/978-1-6684-3595-3.ch013.

Alvarado, R. A. and Rosado, K. A. (2023). Use of gamification as a pedagogical strategy to strengthen the understanding of application problems with rational numbers. *Minerva, 2023*, 64-73. https://doi.org/10.47460/minerva.v2023iSpecial.118.

Arango-Lasprilla, J. C., Rivera, D. y Olabarrieta-Landa, L. (Eds.). (2017). *Neuropsicología infantil*. Manual Moderno.

Becerra-Fernández, C. A. (2022). Effect of gamification-based programs in the school physical education setting: A systematic review protocol. *Journal of Physical Education and Human Movement, 4*(2), 32-39. https://goo.su/3hfsPi.

Bidzan-Bluma, I. and Lipowska, M. (2018). Physical Activity and Cognitive Functioning of Children: A Systematic

Review. *International Journal of Environmental Research and Public Health, 15*(4). https://doi.org/10.3390/ijerph15040800.

Boat, R., Cooper, S. B., Carlevaro, F., Magno, F., Bardaglio, G., Musella, G. and Magistro, D. (2022). 16 weeks of physically active mathematics and English language lessons improves cognitive function and gross motor skills in children aged 8-9 years. *International Journal of Environmental Research and Public Health, 19*(24). https://doi.org/10.3390/ijerph192416751.

Carroll, L., Reyes, A. and Trines, S. (June 23, 2020). Education in Colombia. *WENR*. https://wenr.wes.org/2020/06/education-in-colombia-2.

Chapman, C. D., Benedict, C. and Schiöth, H. B. (2018). Experimenter gender and replicability in science. *Science Advances, 4*(1). https://goo.su/3A8rR.

Chettaoui, N., Atia, A. and Bouhlel, M. S. (2022). Exploring the impact of interaction modality on students' learning performance. *Journal of Educational Computing Research, 60*(1), 4-27. https://doi.org/10.1177/07356331211027297.

Cichy, I., Kaczmarczyk, M., Wawrzyniak, S., Kruszwicka, A., Przybyla, T., Klichowski, M. and Rokita, A. (2020). Participating in physical classes using Eduball stimulates acquisition of mathematical knowledge and skills by primary school students. *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.02194.

Cichy, I., Kruszwicka, A., Palus, P., Przybyla, T., Schliermann, R., Wawrzyniak, S., Klichowski, M. and Rokita, A. (2022). Physical Education with Eduball Stimulates Non-Native Language Learning in Primary School Students. *International Journal of Environmental Research and Public Health*, *19*(13). https://goo.su/vv4ka.

Deng, W., Guo, X., Cheng, W. and Zhang, W. (2023). Embodied design: A framework for teaching practices focused on the early development of computational thinking. *Computer Applications in Engineering Education, 31*(2), 365-375. https://doi.org/10.1002/cae.22588.

Dhar, D., Tarun, J. and Jayachandran, S. (2018). *Reshaping Adolescents' Gender Attitudes: Evidence from a School-Based Experiment in India*. Global Poverty Research Lab. http://dx.doi.org/10.2139/ssrn.3301068.

Doherty, A. and Forés Miravalles, A. (2019). Physical activity and cognition: Inseparable in the classroom. *Frontiers in Education, 4*. https://doi.org/10.3389/feduc.2019.00105.

Education Observatory of the Colombian Caribbean. (November 5, 2023). *Data bank*. https://www.uninorte.edu.co/web/observaeduca.

Feng, Q. (2023). A Study of Embodied-Cognitive Teaching Approach to Teach English Reading in College. *Advances in Education, Humanities and Social Science Research*, *6*(1), 160-168. https://doi.org/10.56028/aehssr.6.1.160.2023.

Freeth, R. and Caniglia, G. (2020). Learning to collaborate while collaborating advancing interdisciplinary sustainability research. *Sustainability Science, 15*, 247-261. https://doi.org/10.1007/s11625-019-00701-z.

Gallagher, S. (2023). *Embodied and enactive approaches to cognition*. Cambridge University Press. http://doi.org/10.1017/9781009209793.

Kolovelonis, A., Pesce, C. and Goudas, M. (2022). The Effects of a Cognitively Challenging Physical Activity Intervention on School Children's Executive Functions and Motivational Regulations. *International Journal of Environmental Research and Public Health, 19*(19). https://doi.org/10.3390/ijerph191912742.

Latino, F., Fischetti, F. e Colella, D. (2020). L'influenza dell'attività fisica sulle funzioni cognitive e sulle prestazioni scolastiche tra i ragazzi in età scolare: una revisione della letteratura. *Formazione e Insegnamento, 18*(3), 124-134. https://doi.org/10.7346/-fei-XVIII-03-20_10.

Luarn, P., Chen, C.-C. and Chiu, Y.-P. (2023). The Influence of Gamification Elements in Educational Environments. *International Journal of Game-Based Learning*, *13*(1), 1-12. https://doi.org/10.4018/IJGBL.323446.

Macedonia, M. and Repetto, C. (2017). Why your body can jog your mind. *Frontiers in Psychology, 8*. https://doi.org/10.3389/fpsyg.2017.00362.

Matute, E., Rosselli, M., Ardila, A. y Ostrosky-Solís, F. (2013). *Evaluación neuropsicológica infantil (ENI-2).* (2ª ed.). Manual Moderno.

Mavilidi, M. F., Lubans, D. R., Morgan, P. J., Miller, A., Eather, N., Karayanidis, F., Lonsdale, C., Noetel, M., Shaw, K. and Riley, N. (2019). Integrating physical activity into the primary school curriculum: Rationale and study protocol for the "Thinking while Moving in English" cluster randomized controlled trial. *BMC Public Health, 19*. https://doi.org/10.1186/s12889-019-6635-2.

Nicolosi, S., Greco, C. and Di Stefano, S. (2017). Integrating Physical Education in the Primary School Curriculum. A Collaborative Approach for Interdisciplinary Teaching. *Formazione e Insegnamento, 15*(2), 91-100.

Rey-Osterrieth, A. (1997). *Test de copia y de reproducción de memoria de figuras geométricas complejas*. TEA Ediciones.

Sattler, J.M., & Hoge, R.D. (2006). Assessment of Children: Behavioral, Social, and Clinical Foundations.

Seiffert-Brockmann, J. and Neureiter, A. (2023). Digital corporate communication and gamification. In V. Luoma-aho and M. Badham (Eds.), *Handbook on Digital Corporate Communication* (pp. 266-280). Edward Elgar Publishing. https://doi.org/10.4337/9781802201963.00030.

Shapiro, L. (2019). *Embodied cognition*. Routledge. https://doi.org/10.4324/9781315180380.

Sibilio, M. e Galdieri, M. (2022). Il potenziale corporeo nell'azione didattica. In V. Boffo, G. Del Gobbo e F. Torlone (Eds.), *Educazione degli Adulti: politiche, percorsi, prospettive Studi in onore di Paolo Federighi* (pp. 191-201). Firenze University Press. http://doi.org/10.36253/979-12-215-0006-6.16.

Smith, C. (2023). Embodied learning in a virtual mathematics classroom: an example lesson. *International Journal of Mathematical Education in Science and Technology*, *55*(4),1084-1095. https://doi.org/10.1080/0020739X.2023.2197906.

Sotos-Martínez, V. J., Tortosa-Martínez, J., Baena-Morales, S. and Ferriz-Valero, A. (2023). Boosting student's motivation through gamification in physical education. *Behavioral Sciences, 13*(2). https://doi.org/10.3390/bs13020165.

Srinivasa, K. G., Kurni, M. and Saritha, K. (2022). Embodied Learning. In *Learning, Teaching, and Assessment Methods for Contemporary Learners* (pp. 177-200). Springer. https://doi.org/10.1007/978-981-19-6734-4_8.

Tanton, T. (2023). Embodied Cognition: Literature, History, and Concepts. In *Corporeal Theology: Accommodating Theological Understanding to Embodied Thinkers* (p. 33-50). Oxford University Press. https://doi.org/10.1093/oso/9780192884589.003.0003.

Vetter, M., O'Connor, H. T., O'Dwyer, N., Chau, J. Y. and Orr, R. (2019). 'Maths on the Move': Effectiveness of physically active lessons for learning maths and increasing physical activity in primary school students. *Journal of Science and Medicine in Sport, 23*(8), 735-739. https://doi.org/10.1016/j.jsams.2019.12.019.

Vetter, M., Orr, R., O'Dwyer, N. and O'Connor, H. (2020). Effectiveness of active learning that combines physical activity and math in schoolchildren: a systematic review. *Journal of School Health, 90*(4), 306-318. https://doi.org/10.1111/josh.12878.

Wechsler, D., Pando, A.C., & López, M.D. (1993). WISC-R: escala de inteligencia de Wechsler para niños-revisada: manual.