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REVIEW ARTICLE

The math game: How motor activity and the use of own body can help in mathematical learning. Systematic review

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ABSTRACT

This work, by means of in-depth research and systematic review, aims to demonstrate whether there is a real and concrete correlation between motor education and the learning of logical-mathematical concepts in school-age children between 6 and 11 years. Initially, several protocols and interventions were selected using targeted electronic databases focusing research on the last ten years. Subsequently, the main theme was addressed, subdividing, and analysing the selected research based on four topics: literature, gesture, interdisciplinary and testing. In the theme "*literature*" two works have been compared concerning the learning of logical-mathematical concepts thanks to the introduction of the use of literature for children and manipulators. In "*gesture*" five works have been compared where mathematical learning took place through the association of gesture with explanation. The nine protocols signed "*interdisciplinary*" deal exclusively with this topic: how the movement and the use of the body intervene on mathematical learning. Finally, three data collection on the topic "*test*": how physical activity intervenes on the results of mathematical tests. Bibliographic research shows that pupils participate with interest in activities and there is no negative influence on this link, indeed a significant improvement was evident in most of the protocols and interventions. There is, however, the need to monitor research in the long term, to expand with a larger sample of children and use larger spaces.

Keywords: Mathematics, Movement, Physical education, Gesture.

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INTRODUCTION

In this article we will deal with the correlation between physical education and the learning of logical-mathematical concepts. We will try to evaluate if, indeed, there is a correlation between these two educationalbranches through the analysis of protocols inherent in the topic.

The functions of the mind have long been considered more important than those of the body. For this reason, physical education has long been devalued in schools, in favour of more academic time. Many studies over the past few years have been trying to overturn this conception, proving that children who practice greater physical activity show better academic performance. In support of this there are also many studies concerning the study of cognitive processes and body movements and how children experience physical and mental benefits when they participate in moments of physical activity. Pouw et al. (2014) study, through embodied theories, howcognitive processes are based on perception and body action. Paas and Sweller (2012) argue that it could be advantageous to use primary information, such as body movements, to help acquire secondary information and, therefore, help acquire knowledge. Many authors also questioned the influence of motor activity in developmental age from Rousseau and Pestalozzi to Piaget and Meinel. Concluding with the theories of intelligences by Sternberg and Gardner.

Thanks to Rousseau (1989) and his theories on the value of the body, numerous scholars have reconsidered the role of corporeality as a natural dimension of the person and as an effective tool for understanding reality. According to Rousseau, knowledge must be guided by observation, by personal experience, by the spontaneity and the usefulness that can derive from it. Pestalozzi (1933) also recognizes the importance of the child's bodily education in its natural progression. Subsequently Piaget (1966; 1967; 1973) correlates the development of the game with the mental one. He affirms that the game, being a spontaneous habitof infantile thought, should be used as the first tool for the study of the cognitive process of the child. A process that develops from an interaction with the surrounding reality through, also, practical knowledge. Meinel (1984), in connection with Piaget, finds in the movement the source of cognitive processes since, according to him, the first basic knowledge takes place through the senses. In the tripartite model of Sternberg's intelligences (1996) we can find the need to use different teaching strategies. According to him, intelligence is expressed through three different fundamental modalities: analytical, creative, and practical. Our school system only evaluates one: the analytical one. There is a need, therefore, to re-evaluate the other two intelligences, because only their combination contributes to the so-called "*successful intelligence*". It consists in the ability to achieve objectives by exploiting strengths, adaptation to the environment and by smoothing and correcting weaknesses. Connectingto Gardner (2002) we can conclude by saying that a school that wants to be inclusive, must consider the differentforms of intelligence and develop them all at the best, considering the different teaching strategies.

We can therefore say that the education of the mind and the body are closely connected. This is not only because already from the early stages of our growth the body acts as a mediator between us and the world, but also because we find important feedback in the regular movement for the correct psycho-physical development of the child. In fact, by educating the body we also favour the physical, mental, and social development of the child and through gestures we construct increasingly complex body patterns and then place them alongside the word, enriching thought (Federici et al., 2008). The body is, therefore, the means by which each individual experiences the environment. We could say that adequate movement activities, controlled and organized in an organic program can interact with educational processes, thus helping children to approach them.To accomplish this, there is a need to move from traditional to more active teaching. The maximum theoretical of this method is Dewey (1968; 1969) that proposes an active school where the child can develop and cultivate activities and interests favouring, also, his natural instinct to do and to act. Learning by doing is the conceptual assumption underlying this methodology. Citing the Italian national indications (Ministero dell'Istruzione, dell'Università e della Ricerca, 2012) we can read how mathematical knowledge closely links making and thinking and to do this the laboratory is important. Laboratory understood as a moment in which the student is active, formulates hypotheses, controls the consequences, designs, and experiments. So, we note that the teaching of mathematics must not be reduced to simple verbal learning, but must be linked to a didactic of doing, of experimenting, leading children to solve real and daily problems of life. The objectives of teaching mathematics in primary schools can therefore be linked to some objectives related to physical education. Both teaching subjects, in fact, propose to prepare children for real life outside the school, learning to relate to each other and the rules to be followed and both help them also to develop their own personality.

In conclusion, the initial hypothesis of this work is to demonstrate how physical activity can help to make many mathematical concepts more understandable. Being able to stimulate the use of motor activities in the learning of logical-mathematical concepts could be advantageous for several reasons: it could help children learn mathematics with more motivation and participation, making this knowledge less hostile, and, moreover, it would help to combat data on sedentary and childhood obesity. The purpose of this article is to evaluate the selected research that examine, precisely, the correlation between physical education and logical-mathematical learning in the developmental age, specifically between 6 and 11 years. In doing so, we want to evaluate the pros and cons of this interdisciplinary relationship, trying to help develop guidelines or future research ideas on this specific topic.

MATERIAL AND METHODS

In support of this research, various articles and research reports have been viewed. Examine the link and interdisciplinary between physical education and the learning of logical mathematical concepts.

Inclusion criteria

The main inclusion criteria concerned the age of the children and the date of publication of the studies. Samples of children between the ages of 6 and 11 have been included, and articles published from 2009 to 2018 have been selected, with one exception. To improve the quality of the research, the protocols were also selected on the basis of the evaluation tests carried out. It was decided to evaluate the interventions that had performed pre and post-tests with qualitatively better. Gradually, protocols were selected that had carried out at least one control test and finally included some interesting protocols related to operations performed without any testing. Unfortunately, it was not possible to include only protocols with large samples and with the mandatory use of pre and post-tests, but this also allowed the evaluation of the importance or not of these aspects. Some articles, thanks to this choice, have been included for the interest and the research ideas they could offer.

Research strategy

Initially, the bibliographic electronic research databases were selected: Eric, ResearchGate, Sport Discuss and Urbis. Almost all the protocols come from the first engine used, namely Eric, since a meticulous search was carried out and many of the selected articles were then found also in the others. Some protocols have been selected through the bibliography of the protocols examined and found thanks to ResearchGate.

The main keywords used for the selection of studies were physical education, motor skills, mathematics, movement, and body. These keywords have been combined with each other in research, even with others as narrative, elementary, developmental age.

For each article found a first selection has been made through abstracts. Some interventions were included in the research, as already mentioned, even if the sample of children was restricted. At this time, a first summary table has been created, generated by a first reading of the fundamental parts of the document. Then, forchosen ones the table was completed in all its entries. Beyond the table a document was created with title, authors, magazine, and a summary of the various selected protocols managed by topic, namely: the use of children's literature and manipulators, the gesture, interdisciplinary between physical education and mathematicsand influence of physical activity on mathematical tests. It was decided to make this subdivision to be able to better view and compare the protocols between them and have a better view of the whole.

Data analysis

The data were extracted in a table initially divided into year and country, title, authors, number of children, activity, duration of experiment, results, magazine, search engine. Subsequently the analysis of theprotocols was carried out in four sub-categories already mentioned above. The first comparisons were made,therefore, by topic, looking at how the various interventions were carried out, considering their duration, thenumber of children, the use of pre and post-tests and the results. Only subsequently these data were further compared with each other to find similarities or differences.

Evaluation risks

The risk of assessment was assessed based on the data collection for each protocol under review. Studies with pre and post-test evaluations were evaluated with less risk, followed by pre or post-test interventions. A subsequent risk assessment is that each study asks for parental consent to include children in the tests and someone may not have joined for several reasons. For this reason, the assessment may have been influenced byinherent self-assessment biases.

RESULTS

After a careful analysis,19 articles met the inclusion criteria and were divided into sub-topics: 2 relating to children's literature and the use of manipulators, 5 concerning the use of the gesture, 9 inherent in the interdisciplinary nature of physical education and mathematics and 3 related to the influence of physical activityon mathematical tests.

The articles were published in a period of 10 years: from 2009 to 2019, except for an article published in 2007. The duration of the interventions varies from a single lesson up to 3 years. Also, the number of children for each sample differs considerably and varies from a single class up to 311. Articles from 5 countries have been included. Most of them took place in the USA, but there are also articles from Turkey, Australia, Holland,and Serbia.

Overall, we can say that positive results have been found regarding the link between physical education and mathematics in all the areas examined, but some studies should be improved and can only be used as a basisfor future research to have more scientific data collection. Furthermore, many topics are still to be explored. It was difficult, for example, to find interventions performed directly in the gym, related to children's literature, or performed on large samples. In none of the protocols examined were damages to logical-mathematical learning due to an increase in physical activity.

Below we analyse the results divided by topic, together with the summary tables of the protocols under consideration.

The use of children's literature and manipulators

Unfortunately, the protocols that bind these three main features are few and all are performed without pre and post-tests and on small samples. It was possible to select only two, described in Table 1, for interest and not for their scientific value. This selection is intended to be an incipit to further encourage this argument with morespecific targeted interventions and better data collection.

Table 1. Protocols of the topic literature.

Title	**Bringing stories to life: integrating literature and math manipulatives**	**Sharing beans with friends**
Year, Country	2018, USA	2013, USA
Authors	Larson L. C., Rumsey C.	Bell C. V.
Number of children, their age	A classroom, 7/8 years	Two classes, 6/8 years
Activity	Teaching of mathematics through the use of literature and manipulation	Mathematical activity on the division carried out on a story, followed by an interview with 4 children
Setting, duration	Classroom, 1 lesson	Classroom, 3 days
Results	The children showed interest	The children showed interest and participation
Magazine	Reading Teacher, v71 n5 p589-596	Teaching Children Mathematics, v20 n4 p238-244
Search engine	Eric	Eric

Both studies take place in the USA on an indefinite number of children between 6 and 8 years and have the duration of a single lesson or three interventions. The data were collected based on observations during theintervention and showed that the lessons were very engaging and motivating. This, as mentioned, can be a starting point for future research: expanding the examined sample, adding pre and post-tests and trying to increase the intervention time as well.

The gesture

In this section 5 protocols have been selected one of which is carried out in the Holland and all the others in the USA. The sample of children for intervention varies from 50 to 118 and they have between 6 and 10 yearsold. All interventions are individual between the child and the examiner and do not take place in a real class situation. Most of them have performed both pre and post-tests. This is a significant point of the real concreteness of the results, even if the effects of the same interventions carried out in the class group are not known.

Two studies where students carry out the action, described in Table 2, have shown the importance of the meaning of gestures, the importance that they are targeted in the learning examined. So, it does not matter that the gesture is explained, but that it is meaningful for children.

This was also highlighted by the other two interventions, described in Table 3, regardless of whether the children onlyvisualized the gesture or reproduced it.

Table 2. Two protocols of the topic "*gesture*" where students carry out the action.

Title	**Moving to Learn: How Guiding the Hands Can Set the Stage for Learning**	**Gesturing Gives Children New Ideas About Math**
Year, Country	2015, USA	2009, USA
Authors	Brooks N., Goldin-Meadow S.	Goldin-Meadow S., Cook S. W., Mitchell Z. A.
Number of children, their age	58 children, 8/10 years	128 children, 8/10 years
Activity	Investigate whether driving children's movements influences mathematical learning	Explore the mechanism by which gestures play a role in the mathematical learning of equivalence
Setting, duration	Classroom, 3 phases of intervention	Classroom, 2 lessons
Results	The activity of the movement has influenced the implicit understanding of the problems	The gesture can affect learning
Magazine	Cognitive Science A Multidisciplinary Journal, v40 n7 p1831-1849	Psychological Science, v20 n3 p267-272
Search engine	ResearchGate	ResearchGate

Table 3. Two protocols of the topic "*gesture*" where student observe the gesture.

Title	**Gesture Helps Learners Learn, but Not Merely by Guiding Their Visual Attention**	**Better together: Simultaneous presentation of speech and gesture in math instruction supports generalization and retention**
Year, Country	2018, USA	2017, USA
Authors	Wakefield E., Novack M. A., Congdon E. L., Franconeri S., Goldin-Meadow S.	Congdon E. L., Novack M. A., Brooks N., Hemani-Lopez N., O'Keefe L., Goldin-Meadow S.
Number of children, their age	50 children, 8/10 years	72 children, 8/9 years
Activity	Investigate if the gesture could influence the visual-motor attention during the learning of equivalence problems by watching some videos	Investigate the importance of the relationship between the gesture and what is said during mathematical learning
Setting, duration	Classroom, 2 interventions	Classroom, 3 days
Results	There is a relationship between gesture and visual attention when the gesture predicts learning	It seems to have benefits on learning
Magazine	Developmental Science, v21 n6	Learning and Instruction, v50 p65-74
Search engine	Eric	ResearchGate

A protocol, described in Table 4, wanted to ascertain whether there were significant improvements also throughthe self-observation of one's own gestures, but this was not observed.

Table 4. Protocol of the topic "*gesture*" with self-observation.

Title	**Watch your stepchildren! Learning two-digit numbers through mirror-based observation of self-initiated body movements.**
Year, Country	2015, Holland
Authors	Ruiter M., Loyens S., Paas F.
Number of children, their age	118 children, 6/7 years
Activity	It investigates how gestures influence mathematical learning.
Setting, duration	Gym and classroom, 2 interventions
Results	Improvements of groups in situations of movement, but there were no significant results inherent in self-observation
Magazine	Educational Psychology Review, v27 n3 p457-474
Search engine	Eric

Interdisciplinary between physical education and mathematics

Many experts think that the movement and use of the body can bridge the gap between mathematical learning and everyday life. To verify this thesis, 9 protocols have been selected mainly from the USA, but also from Australia, Turkey, and Serbia. Almost all the interventions, unfortunately, were carried out entirely in the classroom, only 3 of them were being held in the gym or even in the schoolyard, described in Table 5. The studies carried out entirely in the classroom can be seen in Table 6.

Table 5. Protocols of the topic "*interdisciplinary*" carried out in gym or schoolyard.

Title	**"*Learning Math on the Move*": Effectiveness of a Combined Numeracy and Physical Activity Program for Primary School Children**	**Becoming One in the Fitness Segment: Physical Education and Mathematics**	**The Effects of Integrating Mathematics into the Physical Education Setting**
Year, Country	2018, Australia	2018, USA	2015, USA
Authors	Vetter M., O'Connor H., O'Dwyer N., Orr R.	Griffo J. M., Kulinna P., Hicks L., Pangrazi C.	Thompson S., Robertson J.
Number of children, their age	88 children, 9/10 years	55 children, 8/10 years	91 children, 6/7 years
Activity	Multiplication teaching with an active learning approach linked to motor activities in comparison with a traditional approach	Through the KIA format, mathematics implement in physical education	Integrate mathematical learning in a context of physical education
Setting, duration	Classroom and schoolyard, 20 weeks	Gym, 4 weeks	Gym, 5 weeks
Results	No significant improvement detected	The students responded positively to this teaching model	Integration has improved the learning environment and improved mathematical performance
Magazine	Journal of Physical Activity and Health, v15 p492-498	Physical Educator, v75 n4 p647-660	Masters of Arts in Education Action Research Papers, St. Catherine University, Saint Paul, Minnesota
Search engine	Eric	Eric	ResearchGate

Table 6. Protocols of the topic "*interdisciplinary*" carried out in the classroom.

Title	**Developmental relations among motor and cognitive processes and mathematics skills**	**Purposeful Movement: the integration of Physical Activity into a Mathematics Unit**	**Walk the number line – An embodied training of numerical concepts**
Year, Country	2018, USA	2017, Turkey.	2013, USA.
Authors	Kim H., Duran C. A. K., Cameron E. C., Grissmer D.	Snyder K., Dinkel D., Schaffer C., Hiveley S., Colpitts A.	Linka T., Moellerb K., Huberb S., Fischera U., Nuerka H. C.
Number of children, their age	256 children, 5/6 years	24 children, 8/9 years.	33 children, 6/7 years.
Activity	Explore transactional associations among visual-motor integration, attention, motor coordination and mathematical skills	Integration of motor activities with mathematical learning trying to improve both aspects.	Intervention aimed at the spatial representation of numbers.
Setting, duration	Classroom, 3 years	Classroom, 1 lesson and 2 moment of data collection.	Classroom, not specified.
Results	They showed mutual correlation	There was an improvement in motor activity, but no significant improvement inherent in mathematical learning.	Integration has improved the learning environment and improved mathematical performance.
Magazine	Child Development, v89, n1, p476-494	International Journal of Research in Education and Science, v3 n1 p75-87.	Trends in Neuroscience and Education, v2 p74–84.
Search engine	ResearchGate	Eric.	ResearchGate
Title	**Mathematical terms in physical education curriculum**	**Student Academic Performance Outcomes of a Classroom Physical Activity Intervention: A Pilot Study**	**Students' voices and learning experiences in an integrated unit**
Year, Country	2012, Serbia	2012, USA	2011, USA
Authors	Milanovic S., Markovic Z., Ignjatovic A.	Erwin H., Fedewa A., Ahn S.	Chena W., Coneb T. P., Coneb S. L.
Number of children, their age	30 children, 7/8 years	29 children, 8/9 years	35 children, 7/8 years
Activity	To help students solve mathematical problems through physical education	Realization of pauses of significant motor activity, inherent in mathematical learning	Interdisciplinary didactic unit between physical education and mathematics
Setting, duration	Classroom, 1 lesson	Classroom, 20 weeks	Classroom, 4 lessons
Results	Most students appreciated the combination of these two disciplines	Positive but not significant effects on mathematical learning	It demonstrates the effectiveness of this educational combination
Magazine	Research in Kinesiology, v40 i2 p263-277	International Electronic Journal of Elementary Education, v4 i3 p473-487	Physical Education & Sport Pedagogy, v16 i1 p49-65
Search engine	Sport Discuss.	Eric	Sport Discuss

The age of the children is between 5 and 10 years and the number of them participating in the intervention variesfrom 24 to 256. The duration of these interventions is varied: some last a few lessons, others weeks or even 3 years. These elements are, perhaps, the most significant interventions of the research. Overall, most of the studies showed a significant improvement in logical-mathematical performance after the implementation of motor activities. Even the latter, in general, have improved, but this has not been demonstrated by all the protocols examined. Only three studies did not find significant improvements regarding logical-mathematical learning.

Influence of physical activity on mathematical tests

After analysing various protocols, 3 were selected, described in Table 7. All the studies were carried out in the USA and are performed on samples of numerous children between the ages 8 and 11 years. Although they implement 3 different data collection strategies, all have found that an increase in time spent on physical activity or better motor performance positively affects the results of mathematical tests.

Table 7. Protocols of the topic "*test*".

Title	**Childhood Fitness and Academic Performance: An Investigation into the Effect of Aerobic Capacity on Academic Test Scores**	**Physical Fitness and Academic Achievement in Elementary School Children.**	**Physical Education and Its Effect on Elementary Testing Results.**
Year, Country	2014, USA	2009, USA	2007, USA
Authors	Hobbs M.	Eveland-Sayers B. M., Farley R. S., Fuller D. K., Morgan D. W., Caputo J. L.	Tremarche P. V., Robinson E. M., Graham L. B.
Number of children, their age	96 children, 10/11 years	134 children, 8/11 years	311 children, 9/10 years
Activity	Quantum study of the physical conditions of students and the results of school learning tests	Objectively examine the relationship between physical health and academic performance	Verifies the impact of the hours dedicated to motor education
Setting, duration	Classroom, only data collection	Gym and classroom, 3 weeks	School, 2 months
Results	Having a better level of aerobic health has had a positive impact on academic performance	Several correlations have been identified between physical performance and findings in mathematics tests	Students who received more hours of physical education obtained better scores in school learning assessment tests
Magazine	https://files.eric.ed.gov/fulltext/ED560160.pdf	Journal Of Physical Activity & Health, v6 i1 p99-104	Physical Educator, v64 n2 p58-64
Search engine	Eric	Urbis	Eric

DISCUSSION

This work is a bibliographic search for data collection and the most significant interventions concerning the link between motor activity and mathematics in children aged between 6 and 11 years. Specifically, it wants to be a starting point for the development of future interventions, to understand what to improve and what to focus on. For this reason, topics that do not fully meet all the inclusive starting criteria have also been included.

We found evidence in favour of the interdisciplinary between physical education and logical-mathematical learning. Some studies, however, should be carried out on larger samples and should also include students with difficulties in mathematics. As already noted, it would be necessary to expand the studies that link these two disciplines with narration and try to carry out more interventions in the gym.

Children's literature is important because it supports active involvement and is rich in social interactions, helping to provide even greater enthusiasm and motivation in children. According to Golden (2012) it, in fact, provides important, meaningful contexts during the learning of logical-mathematical concepts. By linking these two concepts to the use of manipulators, you can help children bring everything to an increasingly real and concrete level. In fact, they move learning beyond traditional passive practices towards a more active learning plan that aims to incorporate creativity, critical thinking, and ideas together. In fact, when students use manipulators, they are more interested, active, and engaged in the lesson. Therefore, they can help them connect the various concepts and integrate them with their previous knowledge and skills, helping them to explore their ideas.

Even focused gesture can help in this when used in educational contexts. Various experimental studies have found that children are more likely to learn from instruction that includes speech and significant gestures than from speeches alone (Ping and Goldin-Meadow, 2008; Signer and Goldin-Meadow, 2005; Valenzeno et al.,2003). But most research related to gesture and learning, however, focuses on education based on them and not on their use by children. Even in this work it was difficult to find and select the interventions.

For these reasons, these two sections were introduced between the arguments to evaluate the results of current research and verify if these advantages exist. Though, several studies, especially those on the gesture, were carried out individually and not in a real classroom context, this aspect should also be more developed.

Studies in this regard are increasing considerably on the subject, but there is still a need for more interventions to better understand this link. This research, for these reasons, has tried to bring to the vision thebest interventions carried out over the last few years both in terms of reliability and future interests.

CONCLUSION

Not all the reported data have a scientific rigor, but thanks to the analysis of the examined studies, we can say that an improvement was found both in the educational context and in the performances examined in the various interventions, both as regards the learning of logical-mathematical concepts and motor performance.

However, further studies are therefore needed to address these issues in a more scientific and meticulous datacollection context.

The interest of scholars is growing over the past few years towards this field and this could lead tofurther news on the subject in the years to come, to confirm this we can note that half of the interventions examined are carried out over the last years.

AUTHOR CONTRIBUTIONS

Manuela Valentini: scientific coordinator. Arianna Anelli: bibliographic research. Ario Federici: project coordinator. Equally distributed contribution.

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No potential conflict of interest was reported by the authors.

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