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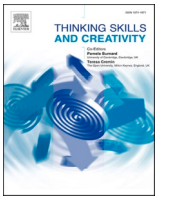

Psychomotricity fostering preschool pupils' long-term learning

Lluis Nogué Vila [a,b,*], Lurdes Martínez Mínguez [a,c,d,†], Dolors Cañabate Ortiz [b,e,g], Jordi Colomer Feliu [e,f]

[a] Department of Teaching Musical, Artistic and Corporal Expression, University Autònoma of Barcelona, 08193 Cerdanyola del Vallès, Spain
[b] Department of Specific Didactics, University of Girona, 17004 Girona, Spain
[c] Coordinator of Psychomotor Education Research Group (2021-SGR-0747). University Autònoma of Barcelona, 08193 Cerdanyola del Vallès, Spain
[d] Red de Evaluación Formativa en Educación, Spain
[e] Teaching Innovation Networks on Reflective and Cooperative Learning, Institute of Sciences Education, University of Girona, 17003 Girona, Spain
[f] Department of Physics, Escola Politècnica 2, Campus Montilivi, University of Girona, 17003 Girona, Spain
[g] Chair of Movement and Languages, University of Girona, Spain

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ABSTRACT

The present research analyses whether an intervention based on employing a grounded psychomotor methodology favours meaningful learning and long-term memorization of curricular content in the same way as an expository methodology would. A comparative analysis between the effects of one methodological intervention and another is performed. The study is carried out with two natural groups of preschool pupils (5–6 years old). The acquisition of content following each of the four sessions programmed for both methodologies, and its memorization in three time frames of 24 hours, 7 days, and 31 days, is evaluated. To evaluate learning and memorization of content, a verbal recognition test and a verbal memorization test are used. The study shows that during the grounded psychomotor intervention, as a methodology that uses meaningful motor skills experienced in an interdisciplinary framework, preschoolers improved their learning. The analysis of the methodological effect was significant despite having found significant differences between groups. Memorization over short (24h), medium-term (7 days) and long-term (31 days) periods of time presents similar values between both methodologies, showing an important recall capacity in both methodologies. In memorization, there are also significant differences according to the group and methodology. The study considers that significant motor interventions experienced as strategic didactic elements are worth considering as a strategy to improve content learning in an educational context at the preschool stage. This study enables us to consider the need to establish mechanisms for preschoolers to control emotional intensity when using psychomotor tasks and delivering intentionally directed curriculum content. A comprehensive examination of the research allows us to contend that although the formative assessment process, which is a byproduct of the learning process itself, has contributed to high memorization results over time, teaching-learning dialogic and constructivist methodologies can be held responsible for very low levels of forgetting.

* Corresponding author at: Department of Specific Didactics, University of Girona, Facultat d'Educació i Psicologia, 17004 Girona, Spain.
E-mail addresses: lluis.nogue@autonoma.cat (L.N. Vila), lurdes.martinez@uab.cat (L.M. Mínguez), dolors.canyabate@udg.edu (D.C. Ortiz), jordi.colomer@udg.edu (J.C. Feliu).
† https://redevaluacionformativa.wordpress.com/.

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1. Introduction

Cartesian inheritance in the educational field has decoupled motor and bodily competences from psychological dimensions (Cañabate et al. 2024). But there are currents in the field of psychomotricity, such as Interdisciplinary Integration Psychomotricity (henceforth PMIi), which consider that using methodological strategies based on experienced motor skills can promote long-term learning and memorization of curricular content.

In the current pedagogical context, motor action is still considered basically physical-motor, mitigating its vehicular potential in the teaching and learning processes of curricular content. This article highlights the pedagogical and didactic potential of methodological strategies that have experienced motor skills as their backbone, as is the case of PMIi, as a resource that promotes learning and memorization of long-term curricular contents. According to Damasio (1999), the body and the brain do not act separately when individuals are immersed in learning processes. Rather, learning is the result of the interactions of body with social and environmental ecosystems. Neuroscience shows that movement allows for a series of experiences to articulate and design the brain (Debarnot et al., 2014). The human body and brain learn not only from analysing their environment, but learning is also the result of interactions with that environment and their social systems (Damasio, 1999). However, the motor experience of individuals, and specifically in students experiencing psychomotor instruction, is not limited to the physical experience of movement, but also to the link between motor skills and emotionality, thus laying the foundations for the theory of embodiment (Brown & Payne, 2009). Meaningful psychomotor learning is the result of individuals considering the limits and possibilities of the body when carrying out physical activities, in developing healthy habits in the practice of physical activities, or in participating actively in individual and group sport showing respect for the rules, one's peers and the environment (Cañabate et al. 2024).

Various studies show the effect physical activity has on learning and memorization processes, especially from a physiological perspective (Bidzam Buluma & Lipowska, 2018; Coles & Tomporowski, 2008; Etnier et al., 2014; Hillman et al., 2008; Mandolesi et al., 2018; Toporowski et al., 1987) and argue that the production and segregation of certain physiological substances generated via physical activity, is normally of an aerobic nature. The effect of physical activity is usually analysed as a precursor and, therefore, as an activity prior to the learning proposal. Etnier et al. (2014) conclude in their study that physical activity prior to a verbal learning activity favours the memorization process. Bidzam-Buluma and Lipowska (2018), in their systemic review, assert that physical activity improves attention, language, learning and memory. Their review addressed several studies of various age groups that show, regardless of the age category, a certain level of physical activity improves cognitive function, especially in relation to working memory, long-term memory, and cognitive flexibility. Daly Smith et al. (2018) also deem that motor physical activity of a certain duration and intensity causes an increase in blood flow and in the production of neurotrophic factors, and that if this activity lasts over time, it will modify brain configuration through the synaptogenesis, neurogenesis, and angiogenesis processes. Mandolesi et al. (2018) state that physical activity provides clear effects at biological and physiological levels that positively affect the brain, and these are powerful precursors to the neuroplastic phenomenon (Dayan & Cohen, 2011; Jaksic et al., 2020). Winter et al. (2007, cited by Coles & Tomporowski, 2008) state that anaerobic physical activity also shows a strengthening of long-term learning and memorization. Coles and Tomporowski (2008) and Haynes et al. (2019) argue that motor skills could have positive effects on consolidating information stored in working memory and consequently on learning and its long-term solidification.

Scientific literature on the assessment of physical activity as a mediator (functional changes that affect learning processes) and as a moderator of learning (from a quantitative perspective) (Guillem Molins et al., 2023) is extensive, defining physical activity as being able to act as a qualitative moderator, shaping the external and explicit cognitive enrichment applied to the motor task. Daly Smith et al. (2018) showed a slight improvement in learning; something which was also reported by Castelli et al. (2014). Bartholomew et al. (2017), Dorđić et al. (2016) and Nielsen-Rodríguez et al. (2021), among others, argued that the use of physically active methodologies increases academic performance. Similarly, Buscà et al. (2006) showed the benefit meaningful motor skills have on learning. Along with this research, Cañabate et al. (2018) postulated that the objective of movement lies in the use of the body as a cognitive, emotional, and relational engine. Thus, we can conclude that an appropriate development of motor competence contributes to physical, mental, and social development (Piek et al., 2006).

In this study, we examine physically active practices, based on promoting cognitive challenges through physical activity, designed to enhance pupils' acquisition and consolidation of learning (Mavilidi & Vazou, 2021). How do we define a cognitively enhanced physical activity (Guillem Molins et al., 2023) or Integrated Physical Activity (Mavilidi & Vazou, 2021; Nielsen-Rodríguez et al., 2021)? Our research is inspired by the study from Duncan et al. (2019) in which they demonstrated that combining movement and storytelling in early childhood education improved learning, specifically in mathematics and spelling. We focus on integrating movement into academic content by employing psychomotor methodologies as a means for teaching curricular content (Nielsen-Rodríguez et al., 2021). Throughout this manuscript we use the term motor skills as a kinesics manifestation of the body. In other words, the psychomotor intervention is built by considering the interaction between body, movement, knowledge, and emotion (European Forum of Psychomotricity, 2024; Pons Rodríguez & Arufe Giráldez, 2016) is significant, emotional, and cognitive dependent. Many authors assume this psychosomatic unity of the child to enhance not only cognition, but also competence development (Rojo Ramos et al., 2022).

Extensive scientific literature supports the concept that emotions influence learning and memorization processes (Cahill & McGaugh, 1995; Carballo & Portero, 2019; Damasio 1999; Morgado, 2016; Phelps, 2006; Ruiz Martín, 2020; Tyng et al. 2017). Phelps (2006), among others, reveals the neurobiological relationship between emotion and cognition through the pituitary-hippocampal axis and limbic system as psychoemotional structures greatly influence cognitive processes (Pessoa, 2008). Morgado (2016) states that a student's emotional experience in a learning situation will largely determine how the learning process will develop. Tyng et al. (2017)

conclude that events linked to emotions - positive or negative - are remembered more than neutral ones.

According to Damasio (1999), individuals will innately register what experiences excite them, whether they be positive or negative, pleasant, or unpleasant. As such, it is necessary to understand that emotion not only awakens and/or maintains attention but, as stated by Labar and Cabezas (2006), situations with a significant emotional charge favour learning and the consolidation of memory when the limbic system is activated and certain neurotransmitters, essential for this process, are released. That said, we must bear in mind that, in accordance with the Yerkes and Donson law concept of arousal intensity of emotional stimulus (Diamond et al., 2007), *excessive* emotional activation can be counterproductive. That is, too much emotional intensity may lead to a state of emotional stress with a consequent decrease in learning and memorization and, therefore, academic performance. According to Phelps (2006), excessively intense emotional experiences should be avoided and that, as argued by Tyng et al. (2017), moderate and acute states of activation that avoid such chronic emotional states should be developed instead.

Learning and memory are conceived as two interdependent, inseparable processes, in which both interact synergistically (Gallistel and Matzel, 2013; Morgado, 2016; Ruiz Martín, 2020). Learning entails processes of encoding, consolidation, storage, and evocation (Ruiz Martín, 2020) which, physiologically, result in the creation of neuronal networks synaptically interconnected (Morgado, 2016). Therefore, learning and memorization can be considered as being constructive and reconstructive processes, on which the durability of learning will maintain a close relationship with the significance of and connection to other pre-existing knowledge (Ruiz Martín, 2020). Ruiz Martín (2020) defined four levels (degrees) of memory. The first degree is *familiarity*, which is classified as something familiar to us. The second higher degree is *recognition*, classified as the awareness of knowledge and identification of information, but with the inability to spontaneously evoke it. The third and more complex level of degree is called *mediated memory*. This allows for information from the memory to be recovered and evoked. Finally, the fourth level *free memory*, is described as the memory that is evoked from a single, simple reference.

On the other hand, it is evident that there is, and must exist, the path of forgetting and avoiding brain saturation. At this point, it is worth mentioning Ebbinghaus's Theory of Forgetting (1885, successfully replicated by Murre & Dros, 2015), which states that the weakening of memory is minimal after a few hours, slight at 24 hours, significant after 7 days and practically residual after 31 days. His study, however, was based on pure non-significant mechanical memorization, contrary to the research presented here.

To analyze the effect of motor skills experienced through the PMIi concurrent with implementing cooperative psychomotor challenges symbolically contextualized (Cañabate et al. 2021) in relation to the teaching-learning processes in early childhood education, two objectives are set:

1. Analyze the effect of the PMIi on the learning of curricular content in the same way as an expository methodology in Early Childhood Education.
2. Assess the impact of PMIi on the long-term memorization of curricula content.

To better understand the effects of one methodology over another when it comes to the pupils' capacity to learn (Objective1) and memorise (Objective 2), the experiential psychomotor instruction is compared to an expository methodology, traditionally versed in the transmission of curricular content.

Both methodologies share the principles of meaningful learning outlined in Ausubel's Theory (Ivie, 1998). The expository methodology is defined as a communicative-interactive model that allows for information considered relevant to be communicated, but favouring and based on the intervention and participation of the students; a model with a certain maieutic inspiration, as opposed to mere rote learning, and based on meaningful learning (Baque & Portilla, 2021).

It is understood as an experienced psychomotor intervention that affects the globality and unity of the person (Aucouturier, 2015; Pastor Padrillo, 2002; Rojo Ramos et al., 2022; Serrabona, 2016), are based on the experience of movement from a cognitive, emotional, affective, and relational significance of what was experienced (Pastor Pradillo, 2002). Within the range of possibilities that this concept covers, there is the discipline known as *Integrative Psychomotor Skills* (Serrabona, 2016) which defines its intervention from proposed motor skills to spontaneous motor skills in order to influence the development of all dimensions of the preschool child. This methodological configuration allows for an interdisciplinary character to be developed through the creation of symbolic learning contexts within the framework of the proposed motor skills.

Specifically, the proposal presented here is carried out through contextualized cooperative psychomotor challenges developed by Cañabate et al. (2021) and specifically adapted to the psycho-evolutionary characteristics of preschool children. This learning strategy is perfectly adapted to the postulates of suggested motor skills (Serrabona, 2016), allowing the teacher to orient the learning objectives to the design of the instruction based on the symbolic contextualization of the challenge. This will always have a motivational, interdisciplinary, interrelational, culturally diverse character, without gender differences and significant for the psycho-emotional development of the child. Ultimately, the challenge becomes an initial proposal that calls for the motor, emotional, cognitive and social involvement of the child to end up co-creating the cooperative psychomotor challenge contextualized symbolically. To achieve this, psychomotor challenges are developed based on 3 principles; guided discovery based on proactive teacher-student feedback, the physical-motor challenge itself as a total expression of the symbolic situation to be solved cooperatively as a group, and by solving the problem due to the inherent cognitive demand of the challenge (Cañabate et al., 2021). Obviously, this process of co-creation involves a constant adjustment of the teacher in relation to the estimated educational objectives, but at the same time it opens an immense door to the creative thinking of the child. It is evident that this psychomotor skill converges with the postulates of interdisciplinarity (Chettiparamb, 2007), developing a holistic and integrative character by diluting the conceptual boundaries between knowledge disciplines and banking on a more competency-based education. In other words, a context that understands the cognitive learning process from the maximum interrelation of neural networks and brain areas and using the transversality of knowledge as a strategy to

strengthen the significance of the acquired knowledge (Carballo & Portero, 2019).

Therefore, the research carried out, regardless of the methodological typology of impact, is developed from a meaningful and non-memoristic perspective. It is based on provoking processes of cognitive dissonance (Harmon Jones & Harmon Jones, 2008) and prediction error (Morgado, 2016) as guarantors of meaningful learning (Ivie, 1998) and thus, this study focuses on the use, or not, of meaningful motor skill experiences in early childhood education.

2. Materials and methods

2.1. Context

Our study was carried out with two groups of pupils aged between 5 and 6 years old and in their third year of preschool education during the 2020–21 school year from November to May. Learning and long-term memory of the contents were assessed over eight one-hour methodological intervention sessions (i.e., four expository-oral sessions and four psychomotor sessions).

2.2. Participants

The sample configuration is ecological in its base as the class group is maintained at all times. Two groups of pupils participated in the study. The first group (group A) consisted of 22 pupils (13 boys, 59.1 % and 9 girls, 40.9 %) and the second group (group B) consisted of 24 pupils (13 boys, 54.2 % and 11 girls, 45.8 %); thus a total sample of 46 pupils (26 boys, 56.5 % and 20 girls, 43.5 %).

2.3. Pedagogical instruction: the teaching-learning and assessment activities

Two types of activities were designed and executed: teaching-learning and assessment. The teaching-learning activities were carried out via two methodologies: expository-oral and psychomotor activities developed during the learning session (we call it acquisition impact). The assessment activities were designed to assess prior knowledge, learning (acquisition) and long-term memorization of the learned content in three time points (24h recall, 7-day recall and 31-day recall) (Fig. 1). They were completed individually and directed by a team of schoolteachers who specialize in early childhood education. Namely, a psychomotor teacher, and four preschool teachers.

2.3.1. Expository-oral activities

In the expository-oral activities, the role of the teacher was based on the conceptual transmission of the topics covered in each of the sessions, so as to develop a narrative (in accordance with the age of the pupils) using visual supports as a didactic resource to promote

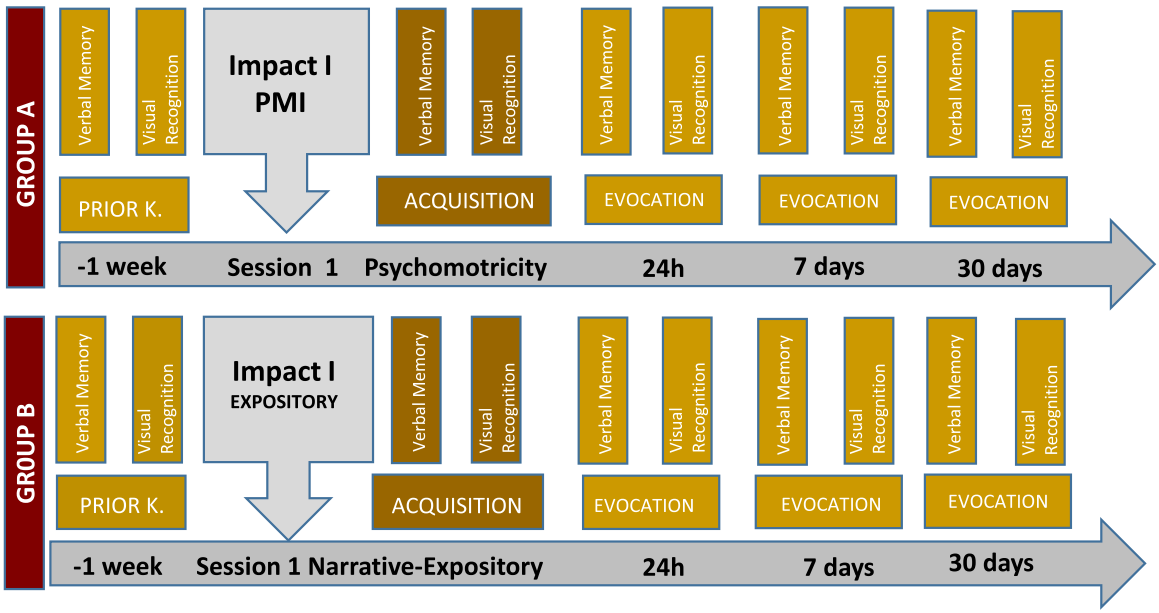

Fig. 1. Desing of activities in each phase

Note:The acquisition session includes the methodological instruction activity (PMIi or Expository depending on the group) and the administration of the two assessment activities. A week before, assessment activities are administered to assess the child's previous knowledge. After the acquisition session, the evaluation activities are administered in three recall sessions at 24 hours,7 days and 31 days to assess the impact on long-term memorization.

curricula understanding. The teaching narrative is based on the concept of a children's story, and uses symbolism to provoke certain emotional involvement. The process of this narrative is based on a maieutic approach (Rojas Drummond et al., 2013), i.e., through a process of interactive question-answers between the teacher and the pupil in order to co-construct a story. This process allowed the key topics to be developed by offering a pupil active-constructive protagonism with constant feedback from the teacher. The activity is complemented by the children colouring in illustrations for each activity. During the expository activities, the role of the pupil is receptive and mentally active (Ruiz Martín, 2020) but does not have a motor component.

2.3.2. Psychomotor activities

The psychomotor activities were developed from the perspective of PMIi (Serrabona, 2016). In this type of activities, students expressed themselves and learnt from experiencing their own movement either individually or in groups (Pastor Pradillo, 2002). The psychomotor activities were framed within the pedagogical instruction model from Cañabate et al. (2021), which essentially describes implementing contextualised cooperative psychomotor challenges in preschool education. This integrative methodology uses pupils' motor skills as a form of motor expression that is systematised, programmed, and intentionally suggested by the teacher. The activity consists in creating an initial symbolic situation, based on scenic elements, which trigger a challenge proposed by the teacher that allows an experiential didàctic with the curricular contents. The teacher's narrative orientations based on the children's contributions and reactions to be established in order to co-create interdisciplinary symbolic motor contexts. For each psychomotor activity, visual support was used to develop a symbolic context. The purpose was to characterize the conceptualisation of the shared narrative creation based on the possibilities of the body and associated movements so as to enhance learning the contents through motor skills (Cañabate et al. 2021). First, in accordance with the content the teacher proposes, a symbolic representational element has to be developed that will facilitate the creation of a symbolic context. Second, a co-created narrative is then initiated, which mimics the expository activities but also incorporates motricity (Bassachs et al., 2020) in challenge form. At this point motor skills become a cognitive and emotional expression of the contents expressed in the symbolic context. Third, the teacher fulfils the wish of their pupils for a spontaneous play activity. Finally, the child has a space for graphic expression to evoke his psychomotor experience.

2.3.3. Assessment activities

To assess the contents learned by the pupils and the long-term memorisation, the research established two assessment activities: (i) recognition of images related to the selected contents, and (ii) verbalised memory of concepts and explanations of selected content. Two instruments were designed to evaluate knowledge acquired and remembered: the visual recognition test (VRT) and the verbal memory test (VMT). The design of both of these tests was based on the Soprano (2003) levels of theoretical argument in relation to the degree of memory: visual recognition (lowest difficulty) and verbal memory (greatest difficulty). It also takes into account the aforementioned four degrees of memory provided by Ruiz Martín (2020): familiarity, recognition, mediated memory and free memory.

The VRT consists of five questions, each with four images related to each of the subjects studied (Prehistory, Ancient Egypt, Ancient Rome, and the Middle Ages), for both the expository-oral and PMIi activities. An image with an associated question allows visual recognition to be identified in relation to the degree of familiarity and the degree of full recognition (Ruiz Martín, 2020). The teaching team scored each question quantitatively on a range of 0 to 1, with 0.5 for identification of the familiar image and 1 for full recognition. To respect the memory degree scale according to Soprano (2003) and Ruiz Martín (2020), this assessment activity was administered before the verbalised memory test was undertaken.

Likewise, the verbal memory test (VMT) is also composed of five qüestions. Each written in the form of a first specific question and referenced to answer a single identifying word (or compound word), and then followed by a second question as an extension of that. The first question was written to suggest a specific memory expressed verbally (mediated memory), while the second question asked for a free and more complex verbalisation to construct the memory (free memory) (Ruiz Martín, 2020). The activity was recorded in video format for a subsequent transcription of the answers.

The answers were evaluated qualitatively, employing six categories for each question on a scale from 0 to 1, with intervals of 0.2. In the case that the child accompanied the answer with a significant gesture (Goldin Meadow, 2010) that complemented it, an added value of +0.1 was given. Note that, the young age of the child and their development in relation to oral language should be taken into account. The concordance between the category and the numerical range allowed the data from the two tests (VRT and VMT) to be the correlated and compared.

Both instruments were validated by eight experts from different disciplines: four experts in education and research, two in physical education and psychomotor skills and two in early childhood education. This range of expert profiles is considered to provide coherence and objectivity to the design of the tests. The interoperability between the teachers' assessment for quantifying pupils' activity was always higher than 90 %.

2.4. Structural and temporal design of the research

A quasi-experimental design of pre and post-test with a non-equivalent control group is used. To provide validity and coherence, four phases of the study were designed to show the comparison between the groups and methodologies, i.e., expository/oral versus PMIi activities. Group A received their first instruction through a PMIi activity, and group B through an expository-oral activity. In this first phase the theme was Prehistory. In the second phase, Ancient Egypt, group A received instruction through an expository-oral activity and group B through a PMIi activity. In the third phase, Ancient Rome, the two groups received the same instruction as in phase one, while during the fourth phase - the Middle Ages - they received the same instruction as in phase two (Fig. 2). The research team intentionally choose historical themes and contents that would arouse interest and excitement among the pupils. The study did

not appraise for the suitability of the typology and appropriateness of the content in relation to the curriculum and the age of the pupils.

Each phase began with an initial assessment activity on the pupils' prior knowledge of the subject and learning content. Each visual recognition (VRT) and verbal memory test (VMT) was administered during the week prior to each activity, hereafter called the pre-test. A second evaluation activity was carried out within a maximum of 2–3 hours (post-test) after each methodological instruction activity (acquisition session). From this point, there were three post-test additional assessment activities at 24h, 7 days and 31 days, based on the pre-established temporary marks in the Ebbinghaus Forgetting Curve (Murre & Dros, 2015) (evocation sessions). The purpose of 1, 7 and 31-day assessment activities was to assess the pupils' temporal permanence of learning and the resilience of the long-term memory process (Fig. 1). For each phase, five VRTs and five VMTs were performed, for a total of 40 tests per pupil. As such, the research had a total sample of n = 46 pupils with each pupil answering 40 tests throughout the whole process, thus producing a total of 1840 tests.

Finally, for the design of both expository-oral and PMIi activities, the confounding variables were treated under equity criteria (definition of contents, expository resources, duration, teacher, temporality, etc.) (Table 1).

2.5. Data analysis

The instrument Statistics 21.0 was used for the statistical analysis of the data. The results of each assessment activity were expressed as arithmetic means on a maximum score of 1. The impact of learning (acquisition) of the two assessment activities (VRT and VMT) was quantified by the difference of the group averages between the scores of the first post-test, administered 2–3 hours after each activity of instruction (and considered to be the total learning value) and the pre-test of prior knowledge, administered ~ 7 days before each instruction activity. Long-term memory was calculated following the same procedure. The result of each time stamp was quantified based on the difference between the result of the evaluation activity (and considered to be the total memory) of the corresponding evocation session and the result of prior knowledge, from which the actual memory could be obtained. The difference between the actual recall value between two time stamps allowed to set the recall value for each interval. This value was constructed to assess the evolution of memorization in the temporality of the study, after 1, 7 and 31 days. The main results are presented in percentages to facilitate understanding.

Cronbach's alpha coefficient for the expository-oral interventions was calculated to be 0.90 in group A and 0.83 in group B, and for the PMIi interventions was calcualted to be 0.85 in group A and of 0.73 for group B. Therefore, excellent internal consistency reliability of the data was ensured. In addition, the results were analyzed considering a mixed linear model. To analyze the interaction between the different study factors, the repeated measures of ANOVA (methodology by group and time markers) was used. Effect sizes were measured with the coefficient η^2.

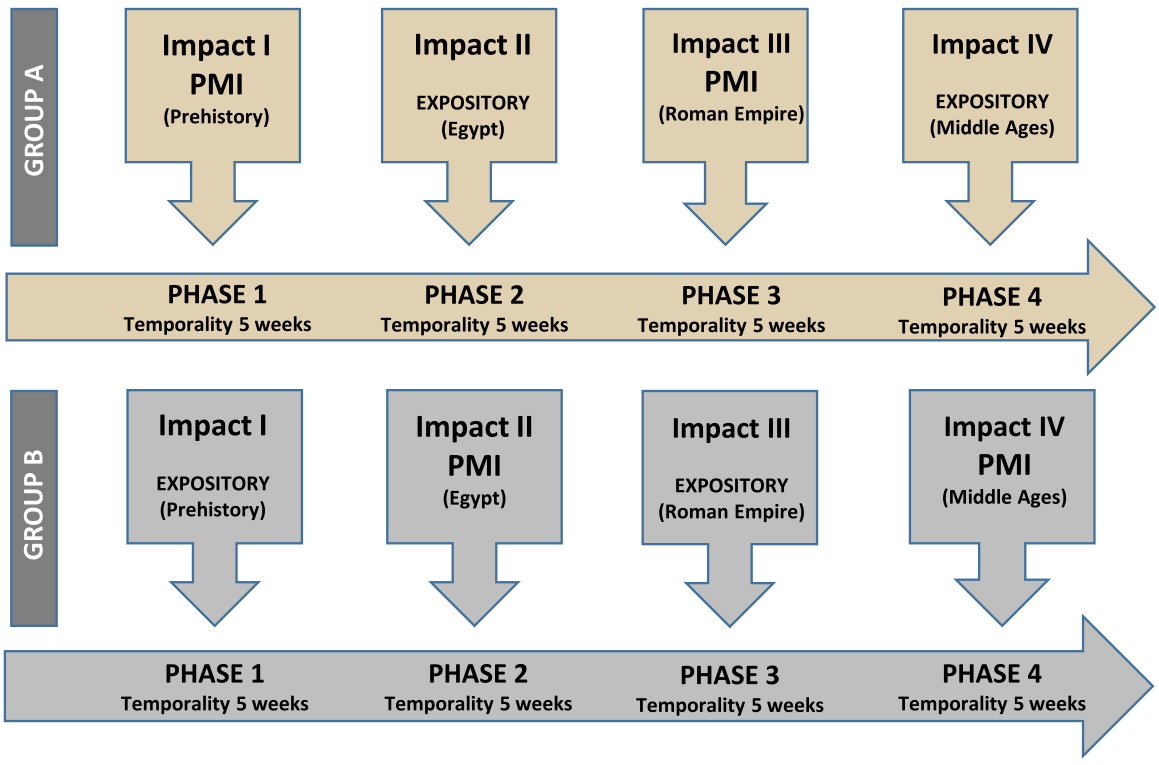

Fig. 2. Phases of research desing.

Table 1
Confounding variables treated on equity criteria.

	Activity PMIi	Activity oral-expository
Temporality	Same day of the impact session (60 minutes of duration)	
Timetable	Session from 9am to 10am or 10am to 11am	Session from 12h to 13h (also PMIi day)
Teacher	Same teacher-psychomotrician	
Contents	Same interdisciplinary curricular content	
Verbal Transmission of Contents	Co-creation of a verbal narrative (maieutic process) in cartoon format to meet a challenge (in first person plural) Meaningful learning from prior knowledge	Same verbal narration (maieutic process) in cartoon/children's story format (third person singular)
Support	Same digital power point support	
Methodological context	Creation of symbolic context	
curricular content	Narrative of curricular content (symbolic story)	
Emotional context	Creating an experiential emotional context	Description of an emotional context
Methodological process	Psychomotor challenges symbolically contextualised	Communicative-interactive and maieutic pedagogical strategy
Activities	Experienced motor activities that identify, represent or express bdily the meaning of curricular content	Drawing colouring activities that identify, represent or express the meaning of curricular content
Transfer between groups	There is no sharing of ordinary spaces or recreation between impact sessions	
Information transfer	Teachers do not teach or promote pedagogical material related to the curricular contents of the study prior to the impact session on children	
Absence of communication of curricular learning content and the type of tests administered to families to minimize reinforcement effects		
Heterogeneity Group	According to the school's organizational criteria, each year the class groups of I5 A and B are configured according to criteria of gender equity, learning levels and special educational needs. (responsible team of I4 teachers and school psychopedagogue)	
Methodological research design with crossover of methodological types of sessions between groups A and B		

3. Results

The results are presented in relation to the research objectives. In accordance with the first objective, the comparative analysis between intervention methodologies in relation to learning (acquisition session) will be firstly addressed. In relation to the second objective, the results are presented in relation to long-term memorization and its inference in relation to temporal markers (evocation sessions). Finally, the analysis will be extended to the group factor and the possible differences between group A and B.

The study based its calculations on actual learning and memorization outcomes at each time stamps by instructional methodology and group. The complete tables of results for the different temporal markers can be consulted in the supplementary material (from Table S1 to Table S5).

3.1. Analysis of the effect of instructional methodologies on learning

To make the respective calculations, the values and the respective averages of the assessment activities of the previous acquisition and knowledge session (**Table S1**) were grouped according to the instructional methodology (group A: 2 PMIi and 2 Expository/group B: 2 Expository and 2 PMIi).

At the visual recognition level (VRT) the results for the assessement of the real learning percentage in PMIi showed an increase of 80.83 %, while a similar result of 71.9 % in the expository was obtained. The differential between methodologies represents a non-significant 8.91 % in favor of the PMIi ($p = .86$). At the level of verbal memory (VMT) the assessment obtained for the real learning percentage in PMI was of 241.3 % versus the 179.93 % obtianed for the expository assessment. A significant difference between methodologies was obtained ($p = .009$) (Table 2 **and Table S2**).

3.2. Analysis of the effects of instructional methodologies on long-term content memorization

The analysis of long-term memorization was carried out based on the three post-learning assessment activities following the time markers defined by Ebbinghaus (Murre & Dros, 2015): 24 hours, 7 days, and 31 days.

After 24h, the Visual Recognition test (VRT), for the PMIi activities showed an imperceptible depreciation at 24h (around 0 %) and minimal in the percentage of real memorization and in relation to the learning value (-0.17 %). In contrast, results of expositoru proved an imperceptible improvement in the real recall (around 0 % too) and a minimal improvement in the real memorization percentage

Table 2
Learning and memoration results between methodologies expressed in arithmetic means and percentatges.

VRT	POST-TEST			24 HOURS			7 DAYS				31 DAYS			
	Real Learning Post Test-K. Prior	% Learning	P (Signification)	Real Recall T24h- K. Prior	% Real Mem. And from learning	P (Signification)	Real Recall T7D-k. Prior	% Real Mem.	% Mem. from 24h	P (Signification)	Real Recall T31D-Prior K.	% Real Mem	% Mem from 7D	P (Signification)
Psychomotricity	0.35	80.83		0.35	-0.17		0.35	-0.96	-0.80		0.36	0.87	1.78	
Expository	0.36	71.92		0.36	0.55		0.37	1.35	0.81		0.40	5.53	4.15	
Comparison Methodologies	-0.01	8.91	.86		0.72	.72		-2.31	-1.61	.47		-4.66	-2.37	.21
VMT														
Psychomotricity	0.23	241.29		0.24	4.53		0.26	9.40	4.72		0.28	15.70	-1.44	
Expository	0.19	178.93		0.21	9.03		0.21	9.07	0.05		0.21	7.62	-1.32	
Comparison Methodologies	0.05	62.36	.009		-4.50	.07		0.33	4.67	.04		8.09	-0.12	.001

Note: The total learning and memorization results are the total averages of the two sessions for each applied methodology according to the VRT and the VMT. The posttest corresponds to the instructional session and is considered the learning value. Prior knowledge shows the results of the average of tests performed seven times before the impact session. The total learning results correspond to the average of the results obtained two hours after the impact session. The actual learning value is considered as the difference between the averages of total learning and prior knowledge. Memorization is studied based on the three time stamps: 24 hours, 7 days and 31 days. To calculate actual memorization follow the same procedure as for calculating actual learning. All the calculations can be consulted in the supplementary material. Values and differences are expressed as percentages. The comparison between methodologies is calculated based on the difference between the total learning or memorization averages and the actual learning or memorization averages. The significance values of the results in relation to the methodological instruction factor are included, regardless of the group factor.

and in relation to learning result (0.55 %). The memorization at 24h showed a very small difference of 0.72 % that was not significant (p = .72). The results of the verbal memory test (VMT) showed, for the application of PMIi activities, an improvement of the percentatge real memorization and from learning time mark calculated to be of 4.53 %, and higher reaching a percentage of 9.03 % when students were immersed in the expository activities. The comparison between methodologies proved to be non-significant (p = .07) (Table 2 **and Table S3**). In short, there were no significant differences in memorization by the students, but the assessment of students showed a stabilization of the content learned during the acquisition sessions.

At 7 days after compelting the activities, the results of the VRT showed in the application of PMI activities, a small depreciation in real memory of -0.96 % while the after the application of the expository methodology an improvement of 1.35 % was found, which means a differential in favor of the expository methodology. The memorization results in relation to 24h reflects the same trend of -0.80 % for the application of PMI activities; versus 0.81 % for the application of expository activities, with a differential of 1.61 % higher for expository activities, although the statistical analysis proved to be not significant (p = .47). For the Verbal Memory Test (VMT), verbal memory resulted were equal between methodologies (9.40 % in PMIi; 9.07 % in expository) defining an inappreciable differential of 0.33 % in favor of PMIi . Taking into account the percentage of memorization in relation to the 24-hour time mark, a substantial improvement was perceived in the PMIi (4.72 %) while it practically remained zero in the expository methodology (0.05 %). The differential in this case was clearly positive and significant (p = .04) for the PMIi of 4.67 % (Table 2 **and Table S4**). In this time stamp, the results showed estability at the level of visual recognition while an improvement in recall for the 24-hour time stamp could be found.

At 31 days, the analysis of the results of the VRT showed some students' asessement recovery of the actual memory. While after the application of the PMIi methodology recovered by 0.87 %, it expanded to 5.53 %, for the expository methodology. The percentage of memorization in relation to the time mark of 7 days presented similar values that tend to an equalization between methodologies. While for the PMIi application a recovery of memorization of 1.78 % was found, after the application of the expository classes it is of 4.15 %. In no case can the results be considered significant (p = .21). In relation to the VMT, the actual recall results were found to be positive and higher in the 31 day time frame, with a 15.70 % after the application of PMIi activities, and a 7.62 % after the application of expositive activities. Even so, in relation to memorization for the 7 days interval, the percentages were very noticeably lower and similar to each other, -1.44 % in PMIi for -1.32 % in expositive, that is to say. In this case the results were calculated to be significant (p = .001) (Table 2 **and Table S5**).

The results support significant learning in both intervention methodologies (Post-test). The little alteration of the results in the different temporal markers express a very low effect of forgetting (Fig. 3).

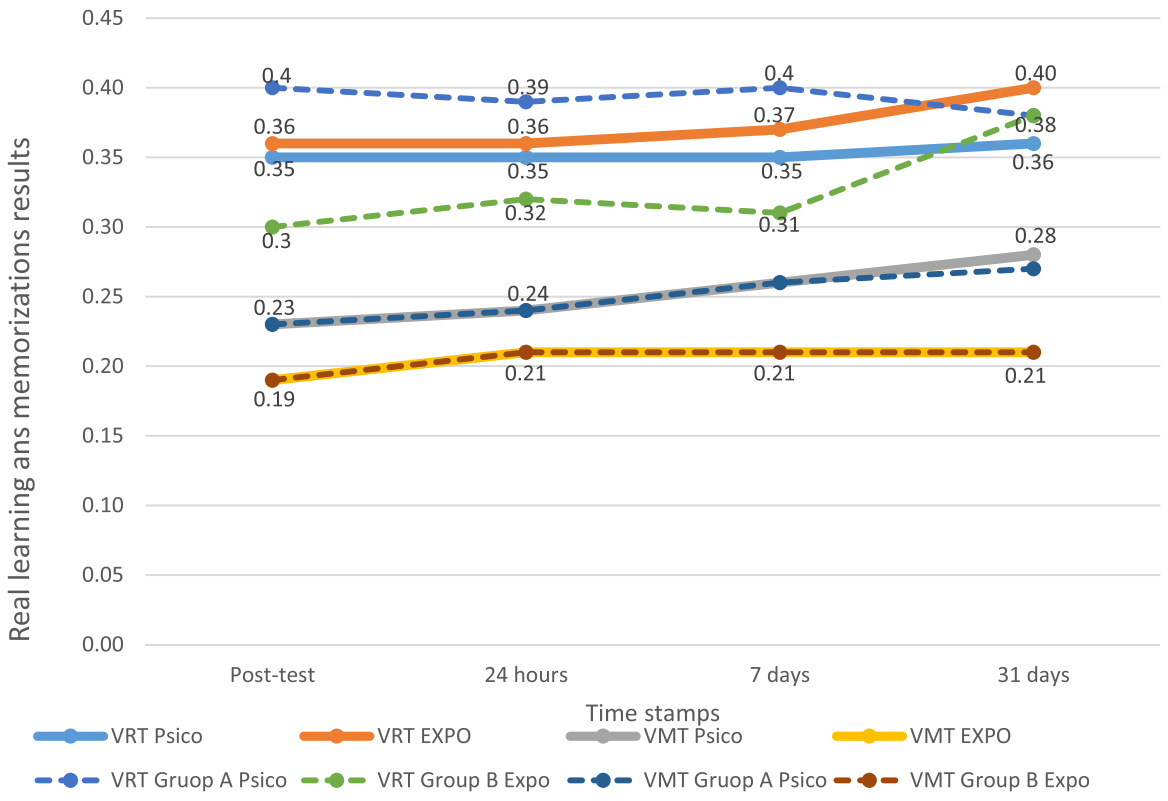

Fig. 3. Evolution of learning and memorization in the different time stamps according to the intervention methodology (continuous line) and according to the group factor (dashed line).

3.3. Analysis of the group factor in learning and memorization

In relation to the generic effect of the group factor, regardless of the methodology applied, the learning results (Post-Test) are considered significant in visual recognition (p = .03) but not verbal recognition (p = .73). The trend is similar in the mid-term memorization temporal markers (24h and 7days), being significant in visual recognition (p = .04 and p = .02 respectively) but not significant in verbal recall (p = .23 and p = .28, respectively). The effect is not significant for both tests at 31 days (p = .83 in VRT and p = .43 in VMT) (Table 3). The results show the possible constitutive effect of respecting the ecological nature of the research groups. Fig. 3 shows the temporal evolution of learning and memorization results in relation to the group factor regardless of the instructional methodology in both the VRT and VMT.

The results of the interaction between methodology and group confirmed the trend shown above. In the Visual Recognition Test the values were significant for all the temporary notes showing that the methodological intervention in PMIi was better valued by the students of group A and, on the contrary, the expository was better considered by the students of the group B. On the other hand, the results of the Verbal Memory Test showed that the interaction was significant at all times (time markers), defining as best the expository methodology for the students of group A and the PMIi methodology for the students of group B (Table 4). The results show the consideration of the incidence of the group factor in the results. Fig. 4 shows the temporal evolution of the learning and memorization results in relation to the interaction between the group factor and the intervention methodologies at the different time points. The graph allows for a greater understanding of significance and interaction values.

4. Discussion

The preschoolers scored higher in learning when they were immersed in psychomotor activities than when expository classes were implemented. The positive results in visual recognition are not as broad or significant as in verbal memory. A plausible reason could be that the images required for recognition in the test have been presented equally in the visual support material in both instructional methodologies and where the incidence of significant motor skills in the learning process was scarce. The significant improvement of preschoolers in learning outcomes in verbal memory during psychomotor activities. On the other hand, improvement of the preschoolers in the learning outcomes in verbal memory during the psychomotor activities could show that the treatment of curricular contents from an experienced and significant motor involvement can improve students' learning processes (Buscà et al., 2006; Lundy & Trawick Smith, 2021; Morgado, 2016; Pesce et al., 2016; Hillman et al., 2008; Piek et al., 2006) and benefit academic performance (Carballo & Portero, 2019, Dordić et al., 2016). It could be said that the effect of embodiment (Kersting et al. 2012) has been more effective in those processes of understanding and internalizing content than those that derive from a recognition of images related to content. This finding would reinforce the assertions of Damasio (2010) and Cañabate et al. (2018) who noted that learning is an inseparable process between the body and the brain, as both interact with the environment, thus favouring their dual involvement in the learning process (Pastor Padrillo, 2002; Serrabona, 2016). Even so, it should be noted that both methodologies have shown high learning impact on the preschoolers' assessment, given that the instructional methodologies used are based on the postulates of constructive and meaningful learning (Ivie, 1998). The positive results of both methodological interventions may infer that any methodology that bases learning on comprehension not memorisation, and generates processes of cognitive dissonance (Harmon Jones & Harmon Jones, 2008) and prediction error (Morgado, 2016) will notably favour the acquisition of both knowledge and associated competences. This argument could explain why the learning results have been more beneficial for one group or another depending on the learning methodology. Meanwhile, meaningful learning would be highlighted as the main factor to explain the highly positive results in both intervention methodologies.

Psychomotor activities operates under several concerns, as such, manifesting kinesic (Pons Rodríguez & Arufe Giráldez, 2016; Rojo Ramos et al., 2022), favouring cognitively motor skills (Guillem Molins et al., 2023), integrating synergies between curricular contents (Nielsen Rodriquez, 2021) and producing affective-emotional experiences (Cañabate et al., 2021; Dordić et al., 2016; Pastor Pradillo, 2002).

The expository interventions, although they undermine motor skills, have also awakened a certain level of emotional intensity in the pupils and experienced through their symbolic maieutic narrative strategy (Rojas Drummond et al., 2013) for which a children's story was used as methodological resource. Thus, both methodologies have achieved a certain emotional involvement of the preschoolers during the learning process (Damasio, 1999; Morgado, 2016; Phelps, 2006).

Employing experimental psychomotor activities versus neutral expository activities gave rise to different levels in academic performance that were associated with levels of emotional intensity (Carballo & Portero, 2019; Ruiz Martín, 2020). Following the law of Donson and Yerkes (Diamond et al., 2007), it is argued that a moderate level of emotional intensity is favourable to learning processes,

Table 3
Distribution values, significance and effect measures in the VRT and VMT according to the group factor.

	VISUAL RECOGNITION TEST			VERBAL MEMORY TEST		
Temporary Test	Distribution F	Sign.	Effect sizes	Distribution F	Sign.	Effect sizes
Post-Test	$F_{Group} = 5.1$	p=.03	$\eta^2 = 0.1$	$F_{Group} = 0.1$	p = .73	$\eta^2 = -$
24 hours	$F_{Group} = 4.5$	p=.04	$\eta^2 = 0.1$	$F_{Group} = 1.5$	p = .23	$\eta^2 = -$
7 days	$F_{Group} = 6.3$	p=.02	$\eta^2 = 0.13$	$F_{Group} = 1.2$	p = .28	$\eta^2 = -$
31 days	$F_{Group} = 0.05$	p=.83	–	$F_{Group} = 0.6$	p = .43	–

Table 4
Distribution values, significance and effect measures in the VRT and VMT according to the group factor and intervention methodology.

	VISUAL RECOGNITION TEST			VERBAL MEMORY TEST		
Temporary Test	Distribution F	Sign.	Effect sizes	Distribution F	Sign.	Effect sizes
Post-Test	$F_{Meth.\ x\ Group} = 23.6$	$p < .001$	$\eta^2 = 0.4$	$F_{Methodology\ x\ Group} = 29.7$	$p < .001$	$\eta^2 = 0.4$
24 hours	$F_{Methodology\ x\ Group} = 28.8$	$p < .001$	$\eta^2 = 0.4$	$F_{Methodology\ x\ Group} = 15.1$	$p < .001$	$\eta^2 = 0.3$
7 days	$F_{Methodology\ x\ Group} = 19.4$	$p < .001$	$\eta^2 = 0.3$	$F_{Methodology\ x\ Group} = 10.9$	$p = .002$	$\eta^2 = 0.2$
31 days	$F_{Methodology\ x\ Group} = 20.3$	$p < .001$	$\eta^2 = 0.3$	$F_{Methodology\ x\ Group} = 27.7$	$p < .001$	$\eta^2 = 0.4$

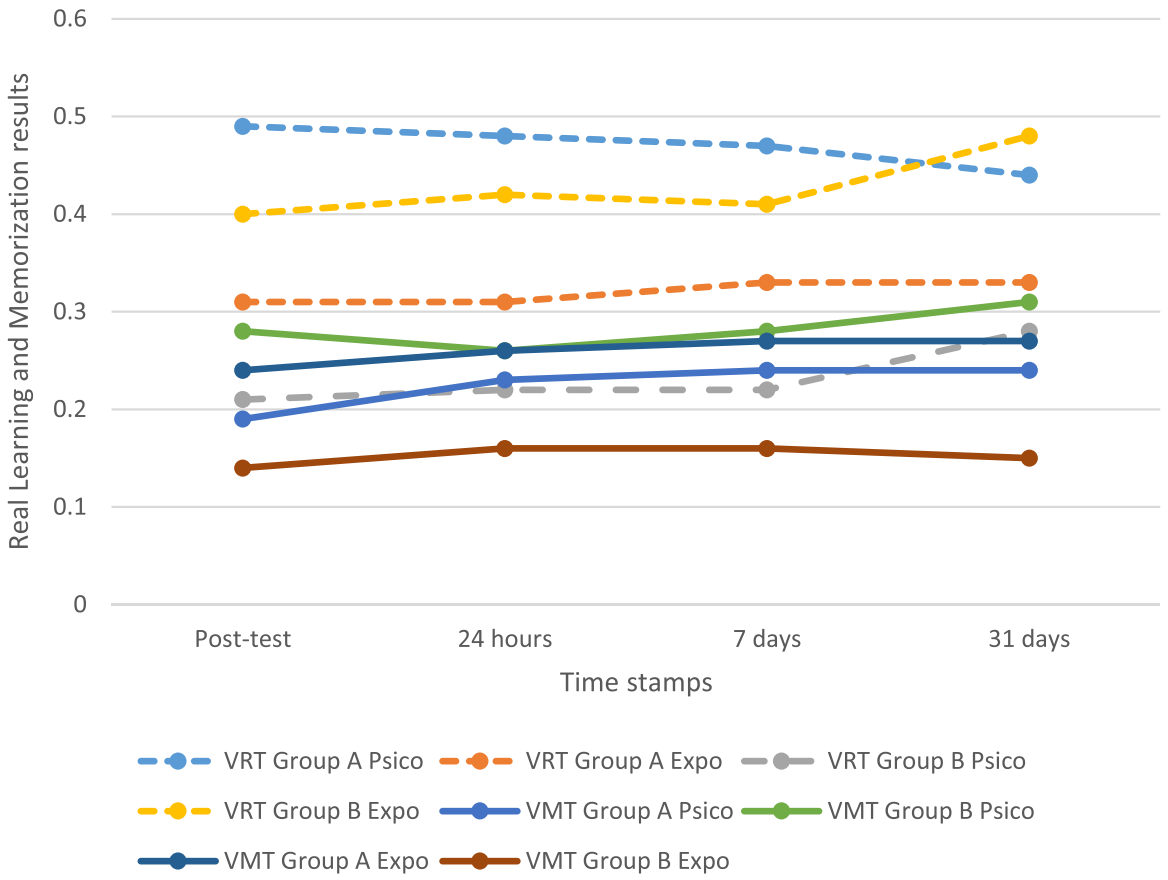

Fig. 4. Evolution of learning and memorization in the different time stamps according to the group and methodology in VRT and VMT.

while a weak or excessive level may not be beneficial.

This analysis allows us to reflect on the need to establish processes of regulation of emotional intensity in psychomotor activities when transmitting curricular content that is intentionally oriented. Likewise, the nature of content and its allegorical exposition in preschool classes, whether it is motor or narrative oriented, has provided a discernible degree of emotional involvement in the learning process. Not only this, the contextualised curriculum subject matter symbolically transmitted may generate a suitable emotional climate thanks to the interest in its historical content and its presentation, whether it be motor or narrative, that is closely linked to a children's story. In this we agree with Miralles and Rivero (2012), who included historical content from historical narratives, dramatizations, or recreations. Thus, it could be argued that the employing teaching-learning methodologies that use motor skills in a meaningful way and favour moderate emotional involvement would improve learning, as long as it respects the principles of meaningful learning. The psychomotor methodology, which promotes significant motor skills that awaken a moderate emotional experience and uses symbolic learning contexts, can be a pedagogical tool in the teaching and learning process toolkit. Therefore, psychomotor activities can favour not only motor, social, relational, and cognitive dimensions, but can also be used as a source for the acquisition of concepts and knowledge (Cañabate et al., 2021). The results would confirm that PMIi can be a feasible methodological strategy that allows the transmission of curriculum content to promote meaningful and creative learning, just as another non-motivational methodological strategy could do that shared the same socio-constructivist postulates. It would seem, therefore, that significant motor skills could facilitate the processes of internalizing content as affirmed by the theory of embodiment (Kersting et al. 2012). The effect of the

positive interaction (p>95 %) of the instruction methodology in both groups at the level of verbal memory, would support this argument.

For preschool children who develop long-term memory, this study would indicate that the students practically maintained or improved learning in the different temporal brands of memorization. Although the general effects of the intervention methodology are significant in the research, the typology of the group does not allow this significance to be extended. In any case, the fairly equal results of memorization between groups in the different time frames would reaffirm that learning

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This argument demonstrates the infeasibility of establishing a standardized graded temporal prediction of the forgetting process when learning is significant and emotionally active. Furthermore, it allows us to deduce the degree of interrelation between what has been learned and previous knowledge, as well as the experience of the learning situation. Thus, it is possible to argue that either from the point of view of the strategy of symbolically contextualized psychomotor challenges (Cañabate et al. 2021) or from the allegorical maieutic narrative (Rojas Drummond et al., 2013), both activate levels of emotional intensity that favour learning (Diamond et al., 2007). At the same time, it is highlighted that the same incidence of PMIi in the learning process, offering verbal memorization, which needs cognitive internalization processes, a tendency to higher and more significant values in PMIi. Even so, the alternating significant results between groups and methodologies according to the type of test (VRT or VMT) do not allow a conclusive positioning.

The results of this study demonstrate a maintenance or significant improvement of the outcomes learnt, with few results showing forgetting. Observing the degree of memory, the outcomes in visual recognition maintain the results throughout the study, with some minimum percentage of forgetfulness that is overcome in the last temporary marks. On the other hand, the outcomes for verbal memory show positive results (with a higher range) in both methodologies. Data appear to support memorisation as a process of progressive consolidation over time, the result and consequence of the process of reconstruction of memory (Morgado, 2016) in the different temporary marks. This argument would make sense of the increased results for both recognition and memory (Soprano, 2003), and would further explain the high results for verbal memory. This premise shows that meaningful memory, a process implicit in the administration of the post-tests administered throughout the study, has a substantial impact on the consolidation of long-term memories (Morgado, 2016; Ruiz Martín, 2020).

Thus, it has been proven that the different assessment activities have promoted the reconstruction of memory, as well as provided an opportunity for the pupils to use and control their own learning (Markant et al., 2016) and that, likewise, they have encouraged them to make an effort to retrieve what has been learned (Karpicke & Roediger, 2008) which, in turn, has contributed to consolidate learning by understanding (Karpicke, 2012; Rowland, 2014). It is worth noting the benefits of activating memory at short and long-term time scales (Carpenter et al., 2022). As such, repeated, spaced, low-emotional-risk memory resulted in a true long-term memorisation activity (Yang et al. 2021).

The additional effort necessary to evoke verbal memory would result in a higher level of long-term memory. Thus, it can be affirmed that using a strategy based on meaningful and experienced motor involvement not only favours learning, but also activates the processes of permanence in long-term memory. With all of the above, it is considered that the integrative and interdisciplinary psychomotor intervention (PMIi) favours meaningful learning and the consequent long-term memorisation of curricular content in the same way as expository methodology does.

5. Conclusions

This study shows that when the teaching-learning processes on pre-schoolers are framed in dialogic processes to promote their cognitive dissonance, both psychomotor and expository methodologies produce high levels of learning. Even so, the higher results in the psychomotor interventions versus the expository ones, evidence the positive incidence of significant motor skills enriched with curricular content. Both methodological interventions promote levels of moderate emotional involvement, a factor that induces high learning values. However, the emotional experience derived from the movement in the psychomotor intervention is an additional factor we proved should be considered. Thus, the application of symbolic contextualization based on the psychomotor challenges in preschool classes allowed students to be immersed in an emotional motor experience cognitively enriched with curricular content that corroborates the postulates of the theory of embodiment in which the body is an inherent element of self-cognition.

All learning involves memorization. The high values of long-term memorization in both methodologies are explained by their socio-constructivist nature in learning based on understanding. It becomes difficult to discern the degree of incidence of motor skills or emotional involvement to argue the durability of the learned content, but it does allow to argue that a significant process of evocation

and spaced out in time leads to a progressive and regulated reconstruction of the learning itself, understood as a relevant factor for the pre-schoolers long-term memory consolidation.

The results have brought meaning to the objectives of the study. The ecological contextual sample allows us to get closer to school reality, but its small size as well as the difference in results and interaction between groups does not allow a generalization. The specific use of an experienced psychomotor intervention does not allow the results to be expanded to generic psychomotor action, but they do indicate the need to deepen the study of motor skills as a vehicular strategy for teaching- learning the curricular contents, such as the cooperative psychomotor challenges symbolically contextualized.

Understanding that PMIi is structured based on cognitive-emotional expression through motor skills, the new lines of research can be oriented, on the one hand, towards the analysis and understanding of the effects that the gradations of emotional experiences in the learning process. On the other hand, the analysis of the effect of motor skills and gesture when it is expressive of cognitive content in learning processes in motor contexts.

For a better evaluation of the methodological effects studied in long-term memorization, it is considered interesting to establish future research that limits the effect of periodic evocation. A methodological design, with more groups and impact sessions, limited to two time stamps (learning and a time stamp at 7, 21 or 31 days) could provide a more in-depth study.

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CRediT authorship contribution statement

Lluis Nogué Vila: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lurdes Martínez Mínguez:** Writing – review & editing, Validation, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Dolors Cañabate Ortiz:** Writing – review & editing, Validation, Formal analysis. **Jordi Colomer Feliu:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Formal analysis, Data curation.

Declaration of competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tsc.2024.101714.

Data availability

Data will be made available on request.

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