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NEW APPROACHING OF MATHEMATICS LEARNING: COORDINATION BASED PHYSICAL ACTIVITY'S SUPPORT

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Abstract: The intuitive and modern concepts of education have become the objects of cross-sectional and longitudinal research investigations contributing to an increased number of research products in several areas of study. It is proved regular physical activities (PA) have a clear positive impact on the cognitive functions at young age. The Variable Sports Ladder 3D (VSL3D) system has a great value with synthesising modern teaching methods into improved student learning. Using the VSL3D system can support areas such as playful learning of Mathematics or foreign language and also social and affective domains of learners. Researchers have created educational games, which help developing an authentic mathematical thinking that ensures the creation, perception and mental representation of mathematical structures. Constructivist learning is also presented in this study with emphasis on connecting PA and learning.

Keywords
Teaching mathematics, VSL3D sports system, constructivism, movement-based learning

INTRODUCTION

Changing educational environment and its challenges:

Based on my 25 years of teaching experience, I think it is safe to assume that what happens at school has a huge impact on our children's advancement, their current and later performance. Therefore, it is important whether students are motivated, they go to school willingly and perform well or it is completely the opposite case. Similarly to other countries, all over the world, the Hungarian educational system is facing significant challenges in the 21st century – to establish success at school, the following elements have become essential prerequisites:

- the introduction of competency-based practice in a traditionally content-based educational system
- supporting cross-curricular approach in a subject-oriented practice
- a renewal by applying student-based, differentiated methodology in an environment based on teacher-oriented methodology
- propagating the integrated and inclusive school model in an excessively selective school system

The application of Variable Sports Ladder 3D sports system in primary education can contribute effectively to meet the criteria set out above. Both the sports equipment with its Hungarian patent and the related methodology provide individual freedom for practising teachers and students equally.

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WHAT EXACTLY DOES THE NAME VARIABLE SPORTS LADDER 3D MEAN?

The equipment is the representative of the new dimension of coordination ladders. In our field of profession, coordination ladders are complex skill developing tools, which largely support training effectiveness. By their application, skill development can be planned easily, particular tasks can be accurately reproducible, which makes the amount and intensity of the work load easily apportionable and controllable. [1], [2], [3].

Regarding material selection and implementation, the Hungarian patent differs significantly from the products that can be found on the market. Bearing in mind aesthetics and functionality the most, the inventors have created their own ladder by improving the existing sports tool. The tool consists of 9 pieces of 45cm x 45cm special (nearly unbreakable) plastic squares and the anti-slip joining elements. A strap makes the carriage and the fixing of the ladder easy and the package also includes assembling instructions and a QR-code which navigates its user to the website. During development, safe use and simple assembly were considered to be priority.

Fig. 1. Variable Sports Ladder 3D

Due to its revolutionary design, VSL3D supports sports experts' job on the most diverse surfaces. Last, but not least, for the first time in the world, the patent contributed to being able to take the thus far regular two-dimensional/ 2D practices into 3D space.

WHAT ARE SOME FURTHER IMPLICATIONS?

The proper application of the sports equipment is presented in two books, one of which organises the movement material of the exercises carried out with a VSL [4], which can be interpreted as a collection of exercises including more than 1000 exercises, meanwhile the other one [5], is a methodological guideline for supporting playful, gross motor skill-based learning in various fields of education. It summarises such best practices that adjust to both the core curriculum and framework curricula, moreover, they encourage the development of a constant interaction with further fields of education and educational forms, and support the development of young children's inclusive and proactive thinking.

They enhance the added value of Physical Education since the opportunities are not restricted to only develop physical abilities in a controlled way, but other areas like Mathematics, IT or foreign language skills can be drilled and acquired playfully.

Not only is the proper acquisition of the movement patterns, i.e. the harmonious implementation of the spatial, temporal and dynamic structure of the movements, the goal, but the complex development of personality is also emphasised. The playful acquisition of the teaching material breaks with the regular lesson management based on rigid traditions, makes the atmosphere more relaxed and encourages cooperative interaction during the lesson, and helps to alleviate subject-related anxiety. The role of the teacher that has now transformed into one of a facilitator can be easily detected, and this, along with the changed student spaces or environment, may contribute to a further alleviation of subject-related anxiety.

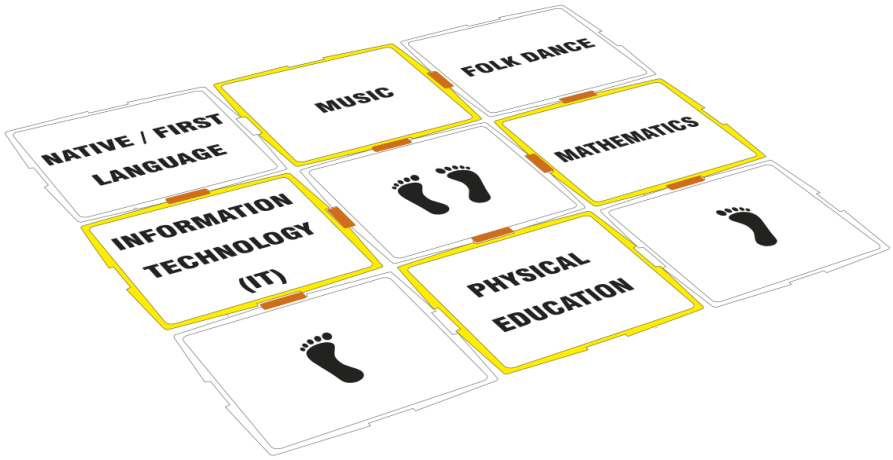

Fig. 2. Subjects that can be learnt with the method

As Fredrickson's [6] broaden-and-built hypothesis shows, besides their various beneficial effects, positive feelings, a relaxed atmosphere, the lack of anxiety widen the focus of attention and open the mind making it capable of assimilating information in a holistic way. Creating the chances and the basis of flexible and creative thinking is definitely a further benefit. The mechanism of effects of the contrary process, i.e. anxiety has a harmful effect on processing information and performance, is also well-known [7]. In our country, Mathematics is the considered to be the most anxiety-provoking subject by Hungarian students, which implies further negative subject-related attitudes and it can be detected in the grades as well [8], [9], [10]. Due to these factors, the efficiency test of the sports system started with Mathematics in the framework of preliminary studies, whose results and partial results are / were presented in conferences on education and sports science (ONK 2020, ONK2021, MSTT2020, MSTT2021).

Over the course of a Mathematics lesson, not only can a student leave their desk and go to the blackboard to demonstrate their knowledge, but the system's special features allow them to be able to transform into a so-called "living calculator" during the playful movement-based learning process. Leaving the desk, either individually or in groups, using their limbs, the student is capable of demonstrating 1-4 digit numbers (where left foot represents - units, right foot - tens, left hand hundreds and right hand - thousands in place value). The student uses their own body to encode and gains experience in the world of numbers and mathematics. A ladder assembled into a 3x3 matrix represents the numbers, 1 is in the top left corner and 9 is in the bottom right one. It may be asked where you can find "0"? Zero can be anywhere outside the matrix. The number is represented by the square in which the limb touches the ground. Let's see an example.

How can the number 3197 be visualized with the help of my limbs?

- Left foot is placed in square 7
- Right foot in square 9
- Left hand in square 1
- Right hand touches the ground in square 3 as the representation of the number.

Fig. 3. The "living calculator

The book titled Fokról Fokra provides assistance in the movement-based course material acquisition in the case of other five subjects besides Mathematics, namely IT, first language, Music, Folk Dance and obviously, PE.
But let's spend some more time with encoding and processing numbers.
Various models have developed whose task is to describe the underlying cognitive processes.
These models are able to and have to manage the incoming information in various shapes:

- written verbal number: "three thousand one hundred and ninety-seven"
- auditory verbal number: the heard number
- written with Arabic numbers: „3197"

Furthermore, students can receive various tasks to be implemented with formulae solved with numbers, e.g. simple arithmetic exercises (addition, subtraction, division, multiplication) need to be solved with them or to estimate the elements of two sets etc.
The third exercise that needs to be managed by the number models is similarly to the input form, the output forms can be various, too, which are determined by the type of the task and our goals.
In our case McCloskey's model is to summoned for help [11]. Based on the incoming information, McCloskey and Macaruso elaborated the steps of the processing procedure of the input form of numbers.
In their model the followings can be considered as input:

- verbal number representation
- graphemic representation
- phonological representation
- representation of Arabic numbers
- representation of Roman numbers

Then the intermediate representation conforming to the type of the input representation, which develops the syntactic framework/syntactic word framework. Consequently, this framework gets encrypted into an inner semantic representation. Similarly, the inner representation first - meeting the output requirements, transforms into a syntactic framework, and finally the desired and expected output form appears.
Let us continue with our example above.
When an Arabic number is an input, and we would like to hear its verbal form, the following processes take place.

- an Arabic number input:
  3197
- syntactic Arabic number framework:
  [[units {3}]multiplier: Thousand[units {1}]multiplier:hundreds tens:{9}units {7}]
- inner semantic representation

{3}10^3 {1}10^2 {9}10^1{7}

- syntactic verbal number framework:
  [[units {three}]multiplier:Thousands[units {one}]multiplier:hundreds tens:{nine}units {seven}]
- verbal output:
  three-thousand-one-hundred-ninety-seven
  Later, other alternative models were highlighted, which I list here:
- complex encoding model - Cambell and Clark (1992)
- the triple-code model - Dehaene (1992)
- preferred entry code model - Noel and Seron (1997)

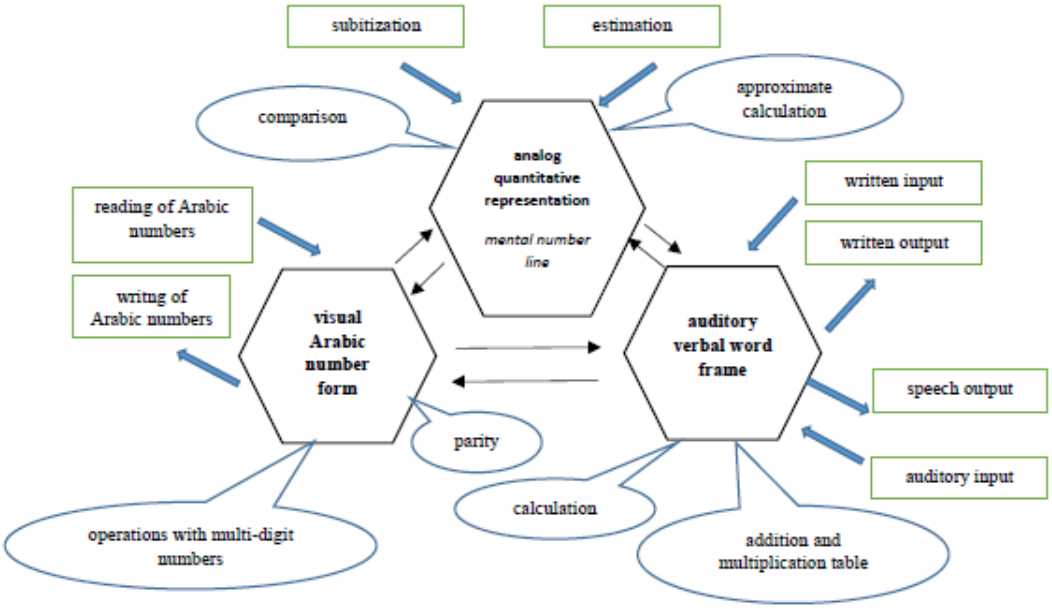

Fig. 4. Dehaene's triple-code model (Dehaene, based on 1992)

On the contrary of the models previously unitedly based on inner representation, the three-code model in Figure 4 supposes three often applied code forms. The first is the analog-quantity code, which is also known as a mental number line, and gets activated when people need to estimate the quantity of objects, or they subitize, which is a quick decision making process giving accurate reckoning of the cardinality of maximum four objects.
The second one is the visual Arabic code, which switches on when people need to process quantities represented with Arabic numbers. The last/third one is the verbal code, which gets activated by numbers heard or represented / written in words.
Three large systems adjust to the three types of codes, the penetrability among them is worked out which ensures the larger flexibility compared to the earlier models. External code formats keep their characteristic features even during the internal process, they do not get transformed into the aforementioned unified semantic code, as it can be detected with McCloskey's model. In this interpretation, the numbers get to the specified processing unit according to their types and the associated operations, such as – analog quantitative representation and their operations: approximate calculation, and comparison; - visual Arabic numerals and their opera-

tions: parity, operations with multi-digit numbers; – auditory verbal word frame and their operations: addition and multiplication tables and calculation.
With the help of the VSL3D sports system we can provide an innovative possibility of mathematical knowledge transfer built on large movements. A piece of sports equipment could be developed into an educational tool which can help relieve anxiety appearing in Mathematics lessons and can contribute to the establishment of necessary and desirable physical activity on a daily basis.
Its recommended value for children is 60 minutes per day, and it is carried out at medium or high intensity [12], [13]. In case of adults, this value related to the amount of physical activity is at least 150 minutes of moderate intensity exercise per week for a healthy adult, as recommended by the World Health Organization. According to the recommendation, it can be 30 minutes of moderate intensity exercise 5 days a week or at least 20 minutes of intensive exercise 3 days a week. Furthermore, it is recommended to perform activities to improve muscle strength and endurance 2-3 days a week. It is necessary to establish the patterns of adult life management even in the childhood [14]. Schools must play a key role in this activity, as declining trends cannot only be observed in the field of mathematics, but it can be clearly detected that the amount and quality of the physical activity of children at the compulsory school age is also decreasing [15]. There is an opportunity in public education to develop our students in a complex way by applying innovations based on movement-based learning [16].
An increasing number of researches indicate that physical activity (PA) can have a positive effect on cognitive functions at a young age [17], [18] [19]. Systematic literary reviews find that there is limited evidence of the effect of physical activity on learning. The existing evidence shows that physical activity is in contact with areas of the brain that support the complex cognitive processes.
The positive effect of moderately intense, short term physical activity carried out in some classrooms on cognitive functions has been proven [20]. The improvement of school achievements was examined in Mathematics and Spelling at students of grades 2 and 3 [21]. Danish children's mathematical performance showed improvement where motor activities were integrated into the learning activity [22]. There was an improvement in students' task management [23], [24], but the exercise had beneficial effects on their mood and emotional state as well [25].
Although cross-sectional and longitudinal studies related to school performance showed favourable results, the results of monitored experiments evaluating the benefits of physical activity on scientific performance are miscellaneous, and further, well-designed studies and researches are required [26]. There are not any references in the literature that increased physical activity in school time – either in the lessons, or in breaks – would have a negative influence on cognitive functions.

THE DIENES WAY, AND ITS NOVELTIES

Zoltán Pál Dienes (1916-2014) was a Mathematics didactic of Hungarian origin, who - as the "magician of teaching Mathematics" - became famous for his playful perception and methods of teaching Mathematics. During his 50-year mission he set the objective to reform teaching mathematics and its international development. He believed that the basic elements of the structures of mathematics can be taught in the form of stories, games and dance, even in the elementary school. He carried with him this principle of teaching Mathematics, wherever he travelled in the world. He expressed his own views on nearly all the continents, and he also compiled the curriculum of the elementary schools of several countries.
In his constructivist interpretation, he compared the school child learning for the joy of discovery with the former perception according to which the aim of teaching Mathematics would

be the transfer of knowledge that could be used in practice. If we insisted on this approach, we would educate, produce "weak calculators" during our pedagogical activity, the efficiency of which also leaves something to be desired. According to the constructivist perception, he saw the aim of teaching Mathematics primarily in the establishment and further construction of mathematical structures [27], [28]. He is criticizing the teacher's effort of knowledge transfer where - in his opinion - the teacher introduces definitions, the symbolic language too early and uses a small amount of illustrative examples. This knowledge transfer provides the understanding of correlations at a sufficient level only for a few, the majority lags behind. Even students who can keep up with the strained pace find no pleasure in learning Mathematics, probably this is the reason why students in our country and internationally consider Mathematics one of the most difficult subjects, they emotionally reject it, and it follows that their commitment to the subject is at a low level [29], [30], [31].

What does the Dienes way recommend instead of the commonly applied exercises?
It urges reforms, it believes in a paradigm shift which changes the way of thinking, the formerly accepted and above interpreted aims of teaching Mathematics. Of course, changing aims bring along methodological reforms, which also result in the use of new teaching aids, whether we want it or not (Dienes cube, Dienes set). What the psychologist-mathematician suggest is no other than the playful way of teaching and learning Mathematics. He did not set the teaching of traditional educational material as his objective, but he was thinking about a deeper understanding, in today's interpretation we might call it competence development. He did not challenge that the world of mathematics and its basic principles are difficult to learn for children, but he did not rule it out that even children can feel and work comfortably in the universe of mathematical thinking. He believed that the adequate learning strategies must be found. If we can establish the appropriate representation of mathematical structures in the mind of school-age children, in the future children will be able to acquire the knowledge of their needs and interest on their own in other fields of mathematics as well.
Children's activity will play a crucial role, in parallel, the teacher's role will also change, the former role of the only source of knowledge will be modified into a facilitator role where the teacher shows the way, organizes work and leads if necessary. As a constructivist, he stresses that it is worthwhile and necessary to place emphasis on internal motivation, instead of external motivations.
The abstract structure must be translated into the language of games (encoding), thus students can acquire concrete knowledge that they can experience - this process is called EMBODIMENT. As far as possible, the same structure must be encoded into more games (MULTIPLE EMBODIMENT)

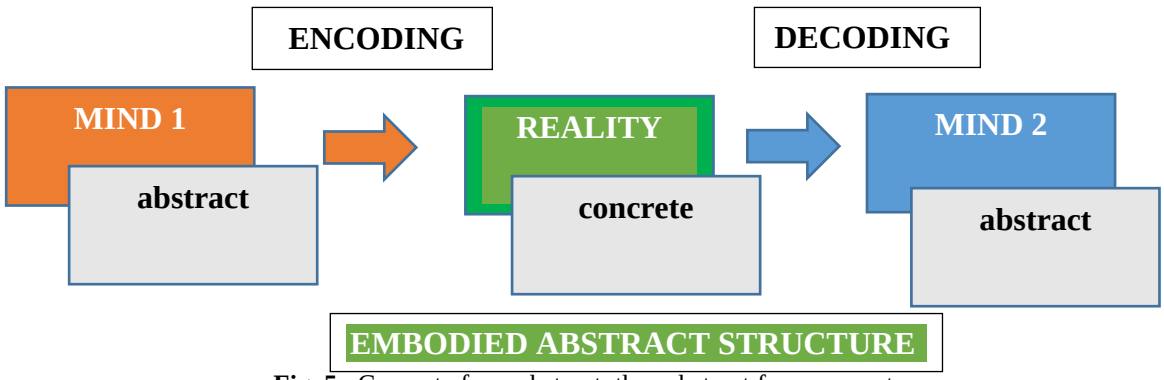

Fig. 5. Concrete from abstract, then abstract from concrete

Let us see how the VSL3D sports system can connect to the above model and to the steps of teaching deriving from it.

1. Encoding the structure into a game – Embodiment of structure (the change from abstract to concrete takes place)
2. Free and structured game – Getting to know the game (the child comes into contact with the structure, gaining relevant experience in mathematics)
3. Multiple embodiment – The birth of the mental picture (filtering the relevant aspects of the structure, recognition of isomorphism)

Steps 1-3 = IMPLICIT LEARNING

4. Symbolization – Translating the mental image into the symbolic language of Mathematics (we can verbalize, it is not only of visual nature)
5. Formalization – The highest level of the abstraction process (the natural language is replaced by the formalized language of mathematics, the characteristics of the familiar structure are expressed in the form of axioms)

Steps 4-5 = EXPLICIT LEARNING

Step no. 1. It can be interpreted as the first step of teaching that the requested structure is encoded into a game, that is the given structure is embodied. The speculative, abstract structure is taken over to the concrete reality.
The analog quantitative representation (mental number line) is visualized with the help of the ladder that is spread linearly, and here the notion of number neighbours can be interpreted. Each square displays the integers between 1 and 9 in ascending order. The two ends of the ladder represent the numbers “0” and “10”.

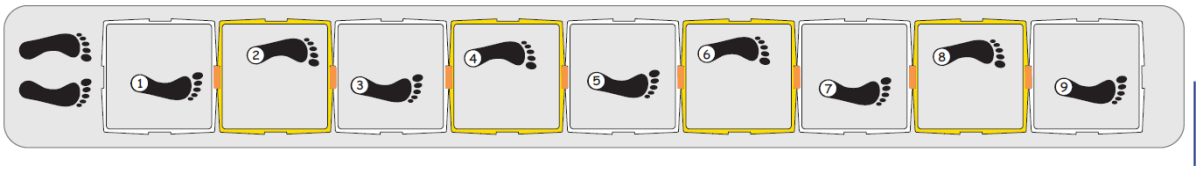

Fig. 6. Number line from a ladder

Each set, as it was already mentioned, contains 9 pieces of ladder frames which can be connected at the sides of the frame in 4 directions. Thus varied and optional forms can be created, which provides an opportunity to respond to our aims, our spatial possibilities (the size of the classroom), individual differences coming from our children’s abilities (differentiated development).
Step no. 2. Free game that is getting to know the embodied abstract structure comes after encoding, as one of the first steps of learning. In that context learning children start to get to know the VSL3D system. They can practice assembly and disassembly, they can build, construct to their liking.
[On a side note, we have learnt a lot from the free games, intuitive constructions, individual solutions of children in the kindergartens and pupils of the elementary schools, which has encouraged us to think further, has contributed to the creation of more versatile methods of use, thus we could arrive at the cube model where we can already talk about abstract concepts related to geometry, edge, side, peak, network, surface, volume, etc.]
It is a characteristic feature of casual, intense games that there is going to be a change in the student’s state of mind as well, they switch into the state of mind of games, which shows analogies with the flow experience of Csíkszentmihályi. The change of the state of mind supports the efficiency of implicit learning, as it can provide access to subconscious contents due to its regressive feature.

The free game is gradually replaced by the structured game which is about discovering the encoded structure and gaining as much relevant experience as possible related to it.

1< 2< 3

Fig. 7. Who are the neighbours of "2"?

For example, three ladder elements are connected: Who are the number neighbours of number two? The "length" of my number line made up of ladder elements is increased, there is an opportunity to identify and to practise more number neighbours.

4< 5< 6

Fig. 8. More and more number neighbours

Step no. 3. With the help of MULTIPPLE EMBODIMENT students are facing systems of different objects but of identical structures. This helps them recognize isomorphism and identify the examined structure.

In case I would like to encode the concept of number neighbour into other "games" as well, I can do it with the help of students sitting behind each other - they make up the numbers. Who will be the number neighbour of whom? Or I place my ladder in the matrix shape (3X3) - who are the number neighbours here?

Dienes draws the attention to the fact that the creation of the mental structure - mental image cannot be expected without multiple embodiment, and he also raises awareness of the fact that recognising isomorphism does not come automatically for small children. In this case the teacher's facilitator, supporter role comes into view, and students must be encouraged to find analogies among the structures encoded in the games. This activity is called "light touch" in the literature. From this point on, it begins to dawn on the child, they will have an idea about the structure itself. It can also be called "enlightment" and "aha experience", a complicated thing that could not be understood finally makes sense, the formerly incomprehensible thing becomes interpretable, a "miracle" happens. Finally, the insight leads to knowledge which is durable, valid, successful and productive [32], [33]. The mental image is born, its existence proves that the new structure is in the student's mind, but this "image" is very haphazard, it cannot be verbalized, that is it is only of pictorial nature. Implicit learning is terminated with the first three steps, the internal image form of knowledge was born, with this, as a structure, students can perform mental and imaginary operations. If the language of more abstract Mathematics is introduced into the process of teaching Mathematics after this, it can help our students to have a better understanding.

Steps 4-5 they represent explicit learning, the higher abstraction levels which are less typical of early childhood, thus they are less relevant from the point of view of the sports system.

Let us return very briefly to the possible consequences of the states of mind changed during the game [34], [35].

- The subjective personal experience reaches a supernormal attentional, emotional and cognitive level.
- The field of consciousness is restructured (salience landscape), other things will be relevant than formerly.
- An increased cognitive capacity which makes it possible to process information and to learn more effectively.
- There will be a quality developmental leap which is characterized by the following side effects:
    - Increased skills - altered brain networks
    - Growth in cognitive capacity and efficiency
    - Knowledge growth - the network of mental representations is supplemented by new complex structures
    - Increase in cognitive complexity - better knowledge, better cerebral wiring, new cerebral patterns

THE IMMEDIATE FUTURE

We are planning to continue examining the effectiveness of the system in the field of education of Mathematics. We hope that from autumn in-person education will be provided continuously, which is essential for the realization of our complex two-group pedagogy experiment. In the framework of the intervention we would like to study the complex interplay of the Variable Sports Ladder 3D sports system, together with the achievements and subject commitment of elementary school students (pupils) in lower grades. The role of movement in cognitive learning has already been proved by various methods and tools, but in the previous examinations the role of conditional abilities has been given attention. It can be assumed that the development of coordination abilities can promote the acquisition of the Mathematics material in an easier, more eventful way. We are looking for these answers in the immediate future.

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