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Stimulation and Development of Intellectual Abilities in Preschool-Age Children

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Abstract: The paper is focused on the investigation of impact of created experimental natural scientific programme for preschool-age children. Our programme concentrates on physics teaching adapted for preschool age in which children have possibilities to make experiments themselves—empirical cognition. Its innovation with respect to other stimulation programmes implemented in the past consists of including connection and thus developing a wide spectrum of intellectual abilities. Primarily, we are focusing on the impact of stimulation programme research on selected psychological variables, specifically intellectual abilities—intellectual maturity. Its second aim is to compare and test the validity of drawing tests designed for intellectual-level investigation of preschool-age children, school maturity, and school readiness. The obtained results do not provide evidence in support of the stimulation programme on developing intellectual/conceptual maturity. The results of the second part of the research (i.e., drawing) shows that the indicative level of intellect, perception, and motor maturity are closely related.

Keywords: stimulation; programme; intelligence; abilities; drawing; children; preschool; experiments

1. Introduction

Intellectual abilities, their level, possibilities of development, stimulation, and predictability of success are still a topical theme in the field of psychology. Despite quite a strong influence of genetics, external factors play almost half of part-share in their formation [1]. Among the environmental factors, there are, for example, a stimulating environment in which the child is raised, stimulation of communication, sufficiency of books and learning aids, characteristics of family—education, economic status, etc. [2,3]. That is the reason that the attention of psychologists, educators, and instructors has been focused on the area of stimulation, facilitation, and development of these abilities from a very young age through various programmes implemented in the current education.

As in the past, nowadays there are also many implemented and innovative programmes for improvement of intellectual–cognitive abilities. A theoretical background of development/stimulation programmes is created by the constructivist theory of learning. The essence of stimulation programme is to encourage and stimulate through certain systematically created tasks, operations, games, and exercises. Each task, game, and exercise focuses on the development of those psychical functions, which emphasize speech, mathematical, physical, perception, graphomotor, creative, or other abilities [4].

The aim of this experimental study is to investigate whether a stimulation programme focused on empirical cognition in the conditions of a nursery school will show a significant increase of intellectual/conceptual maturity of children.

Improvement of intellectual and cognitive abilities have been implemented through upgraded and innovated programmes for a long time up to the present. For example, abstract thinking [5], logical thinking of children 6–14 years old [6], ability to understand the meaning of words from the context [7], and practical intelligence [8,9] were inspirational studies for our research.

Other inspirational programmes were implemented within the Slovak educational system. Creativity of preschool-age children [10,11], intellectual abilities of preschool children [12], mathematical abilities of Roma young-school-aged children [13], and specific intellectual abilities of various disadvantaged children [14,15].

Our programme focuses on physics teaching adapted for preschool-age children through the possibility to conduct experiments by themselves. We follow Jarome Brunner´s approaches to science learning, because he believed that children learn best by discovery. He suggests that the aim of education should be intellectual development, and science curriculum should foster problem-solving skills through inquiry and discovery: "Any idea or problem or body of knowledge can be presented in a form simple enough so that any particular learner can understand it in a recognizable form" [16] (p. 46).

Being inspired by Brunner's ideas, our stimulation programme focuses on empirical (research) cognition in the area of physical phenomena in a unique way. Its innovation with respect to the stimulation programmes implemented in the past lies in the above-mentioned connection and development of a wide spectrum of intellectual abilities.

People pay great attention to differences between individuals—how they think, decide, how fast they are able to adapt themselves, to teach, and make smarter and better things than others. The desire to get to know the origin, the possibility to improve themselves, and the reasons of the differences led to the investigation of what we call intelligence. It is created by various internal and external factors responsible for positive or negative growth and stability. School and school environment also have a very important impact. It has been proved that the higher the school demands are on intellectual abilities, the higher the score/performance of pupils is in intelligence tests [17].

1.1. Preschool Age and Education

The period of preschool age is the most important part of human development. The nursery school and family try to achieve the goal that leads to a child's personal development, familiarization with the life in society, and preparation for school.

Education at nursery schools in Slovakia follows State Educational Programme—ISCED 0 for education of children in preschool institutions. The curriculum contains education areas, content, and performance standards—compulsory content and competencies, as well as evaluation questions, which need to be managed by the child after completion of the education.

The children at preschool age are very sensitive, and in addition, they have adequate possibilities to discover new things and obtain information about it. It is important to develop positive emotional relation to nature, diversity, and beauty, and teach them to use and protect them at the same time. Particular educational areas are developed later, at higher classes at primary school, and they are closely connected. Stimulation of spontaneous thinking, exploration, and play oriented to using scientific methods enable the child to answer questions about the world and fulfilment of the innate desire to know [18]. The research of Ozgenel et al. [19] pointed out the effect of enriched workshop training given to preschool children focused on creative thinking skills. The research of Mara [20] shows the importance of socio-emotional development of preschool children as an essential component of schooling ability.

The influence of environmental factors on intellectual efficiency of preschool children was investigated by Jovanović et al. [21]. The abilities of visual and motor coordination and attention proved to be the most sensitive to the influences of environmental factors. Development of emotions and intellect can also be achieved from drawing activities, as the research of Randoha shows in [22]. Drawing facilitates intellectual, emotional, and physical development of the child—cognition, feelings, perception, thinking, imagination, will, and emotions.

At the age of 4–7 years, the drawings of children are expressionistic and subjective. According to the statistical study managed by J. Thomazi, the human trunk appears in the drawings of children at the age of 5–6 years. Human figures are portrayed from the front. At the age of 6, the body is complete with all extremities. According to this study, 71.5% of children drew extremities only as lines. In 33% of cases, hands are connected with the body on the correct place and 4.3% of them have marked arms [23].

Development of preschool children's intellectual skills in arts classes are closely connected with drawing, as was published by Priede and Vigule [24]. They pointed out that things that enrich a child's personality, physical, intellectual, and mental world largely depend upon the surrounding environment, the people closest, and society in general. Artistic and practical activities include thinking operations that stimulate acquisition of intellectual skills.

In the preschool age, the stimulation and influence of adults is of primary importance, because self-development is considerably limited, although not completely. An effort of the stimulation programme is to induce external, educational conditions and climate, which enable individuals to develop and update their innate potentials and developmental reserves [13].

A theoretical background of a stimulation programme development is the constructivist learning theories, such as the work of Vygotskij [25] and Bruner [26].

1.2. Natural Sciences and Education

Information and competencies from the field of science in the conditions of Slovak education contain all educational sub-areas: Perception of nature, plants, animals, human, inanimate nature, and natural phenomena. The cognitive area contains knowledge about four seasons, plants, animals, nature, water, weather, and basics about the Earth, Sun, and universe.

1.2.1. Study of Natural Sciences is Realized in two Ways:

1. *Random*—the child learns about nature at school and home environment spontaneously. He or she observes, researches, explores, takes interest in, and asks about the areas attractive to them. Nowadays, media (internet, TV, radio) also plays an important role.
2. *Systematic*—follows the particularity of child's age, taking place in relevant institutions—nursery schools. It uses methods, procedures, and concerns reaching goals [18].

Leading to science literacy occurs during the whole life of man's education, and interaction with parents, classmates, persons of the same age, and other authorities accompany the child during his or her development. Children and their "settings and hunger for" explore phenomena, activities, and relations that are interesting to them. It is necessary to provide them the space for investigation and examination of these needs. We present, for example, performance standards that should be acquired by children after they complete the programme of natural phenomena.

The educational process and activities are based on inspirational, stimulation situations supporting the effort to recognize natural facts. "The child describes chosen natural phenomena and changing conditions of its functioning on the basis of their own investigation and exploration, light and shadow, heat and burning, melting and solidification, vaporization, dissolving, sound, force, and movement" [18] (p. 56).

The teaching process is a systematic activity with a specified educational goal—acquiring of knowledge through special experience procedures. It has its beginning, means (form, method), and goal. There is a certain problem—a question specified by pupil's needs and interests at the beginning of the educational process. The goal of learning is the learning product, knowledge in the form of the most realistic picture of the subject knowledge, or development prediction and learning movement or form of optimal picture and its practical recast [27].

1.2.2. Important "Equipment" or Methods in Physics Teaching are:

1. Experience, experiment, and empiricism.
2. Scientific system of knowledge (methodology).

Methods of cognition in physics are used for knowledge acquiring. Quantitative and qualitative empirical data are obtaining by empirical methods of knowledge—investigation, measurement, and experimentation.

Progress appearing from scientific/empirical facts (empirical knowledge) is the working method of experimental physics. Comparison, measurement, and experiment are used for obtaining empirical data processing by the theoretical method of knowledge, and thus they are formulated as empirical/scientific facts [27].

Natural science competencies are possible to be developed at preschool age by observation (purposeful information obtaining from environment), categorization (comparison and categorization on the basis of goal-directed observation), and empirical communication (expressed by argumentation, own experience). It is necessary to also focus on the creation of children's questions and the way they try to look for answers. The important issue in this field is also the development of capabilities to conditions. Conditions naturally lead the children to examination of objects, effects, and situations by the method of trial and error or by simple observation [18].

According to the previous implemented programmes, we deduce the following hypotheses and research questions:

Hypothesis 1 (H1). *We predict that the group of preschool-age children (EG—experimental group) participating in the stimulation programme will show statistically significant intellectual maturity in comparison with the control group (CG) not participating in the programme.*

Hypothesis 2 (H2). *We predict that the group of preschool children (EG) participating in the stimulation programme will show statistically significant results in intellectual/conceptual maturity (subscore of content elaboration) in comparison with the non-participating group (CG).*

Hypothesis 3 (H3). *We predict that the group of preschoolers participating in the stimulation programme (EG) will show statistically significant difference in comparison with the non-participating children (CG) in intellectual/conceptual maturity—formal elaboration.*

Hypothesis 4 (H4). *We predict that there is a statistically significant relation between evaluation of intellectual maturity and school capability (Goodenough Draw-a-Person Test and Test of school maturity by Krogh–subtest: Drawing a figure).*

Hypothesis 5 (H5). *We predict that there will be a statistically significant relation between evaluation of school maturity and capability (Test of school maturity by Jirásek–subtest drawing a figure and Test of school maturity (capability) by Krogh–subtest drawing a figure).*

Research question 1 (RQ1). Is there any statistically significant positive correlation between the drawing test of intellectual/conceptual maturity by Goodenough and test of school maturity by Jirásek?

Research question 2 (RQ2). Are percentage results of chosen drawing elements similar to results of the Thomazi statistical study?

2. Samples and Methods

2.1. Samples

Our research sample consisted of 50 participants—children from four nursery schools in the city of Nitra, Slovakia. The participants were 5 to 6 years old. They attended the last year at nursery school. The written informed consent for research was collected from the parents of all the participating pupils.

An experimental group participating in the stimulation programme contained 28 children at an average age of 5.58 years with the standard deviation SD = 0.43. The control group, which was not participating in the stimulation programme, contained 22 children of an average age of 5.31 years with the standard deviation SD = 0.29. On the basis of pretest (Jirásek test of school maturity–subtest of human figure drawing), the groups were not significantly different.

The age of participants was selected on the basis of studies dealing with intelligence development (from 3 to 15 years). It shows that the most dynamic phase is concentrated to the first 8 to 10 years of children's lives.

2.2. Methods

The stimulation programmes took 10 months (which is one school year in the Slovak educational system) and it was led by a researcher—Dr. Valovičová—as an experienced teacher of experiments in preschool education. The children were involved in research for 1 h every 2 weeks. Except the experiments at nursery school, the children usually also received homework (which meant extra activities for practicing new knowledge at home or out-of-school environment).

We implemented the following comparative, inter-subject, quasi experimental research plan:

1. Experience, experiment, and empiricism.
2. Scientific system of cognition (methodology)—empirical data are obtained by empirical methods of cognition by observation, measurement, and experimentation.
3. Theoretical methods of cognition are used in mental acquisition of empirical data:
    a. Logical methods (e.g., analogy, analytic-synthetic, and inductive, deductive methods, mental processes, abstraction, concretization, generalization), which are an inseparable part of intellectual abilities.
    b. Cybernetics methods (analysis and synthesis of systems, method of trial and error, modelling methods).
    c. Methods of problem solving and elemental mathematical methods [27].

2.2.1. Procedures of Research Measures

The programme was divided into three levels on the basis of theoretical knowledge about pupil's empirical cognition and creativity development. The research was realized as follows:

1. The level is entitled **"Investigate and Getting to know".** Physical topics were introduced by interactive experiments at this level, and children could join in according to their own choice. For example, in the thematic unit Liquids, we introduced information through experiment—liquids are not compressible using closed syringe filled with various liquids (vinegar, oil, water, alcohol). Children tried to push on syringe—they saw and tried on their own that it was not possible [27].
2. The level is entitled **"Explore"**—Children tried to solve a task (problem solving) quasi individually and learn new knowledge. This level follows after the first level. Children should draw information from the first part of the programme. In the topic Liquids, children put various things into a filled measuring glass and observed which object pushed more water outside (e.g., small balls, beans, etc.). When the children were conducting this experiment, we observed whether they understood what they were doing, and we would let them conclude which object pushed a maximal amount of water from the measuring glass [27].

3. The level is entitled **"Teach others"**—Children should teach their parents and relatives what they learned by experimentation. Children at this age obtain new information very fast and remember it for a long time, mainly if they learned through play, and information was presented in an interesting form. This kind of feedback brings teachers information about understanding of children (if they learned a given topic correctly, and what is the most interesting thing for them) [27]. This process was evaluated by children through the conversation with them. We also involved parents in this process. Their task was to write their child´s impressions of the experiment, their experiences, and impressions. Parents also filled a questionnaire with the child twice in the school year (in January and June). The questionnaire focused on activities of children, their experiences, emotions, and it gave feedback on the scale from +5 to −5. We compared two questionnaires of every child and evaluated them according to the obtained results (−5 to −2 meant decrease, −1 to +1 no change, +2 to +5 progress).

The questionnaire contained 21 questions divided into 3 groups focused on the above-stated aims—cognitive, affective, and psychomotor aims. The cognitive aim was connected to learning (if the child talked about the nursery school at home; if children tried some experiments at home; etc.). The psychomotor aim was connected to improvement of the skills (better in pouring the water; did children do their homework?). The affective aim concerned how children evaluate physics with respect to other activities at nursery school (e.g., theatre, magician, etc.). The questionnaire contained the introduction with instructions and examples for the correct use.

2.2.2. Measures Instruments

The dependent variable—level of intellectual abilities—was measured by the Goodenough Draw-a-Person Test [28] for intellectual/conceptual maturity adapted by Šturm and Vágnerová [29]. The test is usually used for the identification of mental stage and development of intelligence—intellectual/conceptual maturity. It is possible to apply it to children from 3 to 13 years old (mental age). The basic instruction is to draw figure of a person. A finished picture is evaluated, and the result is assigned to the mental age by using a table. It can also be expressed by the intelligent quotient—calculated as the equation: Mental age and chronological age times 100. The psychometric characteristics of test were: 35 items of test were chosen from the original 78 items after 2 items analysis and elimination of those which differentiate inadequately.

Drawings were evaluated on the basis of the 35 items. Fifteen of them focused on content (intellect) and 20 on evaluation of realization level, i.e., forms (perception, motor activity, intellect). By counting the score and completion of item, we obtained the content, formal, and total score. Content realization is usually done before formal [24,29,30].

We used Krogh test of school maturity (adjusted by Gajdošová and Herényiová [31]) subtest of human figure drawing and Jirásek test of school maturity [32] subtest of human figure drawing. It is a well-known drawing test for screening of maturity for preschool-age children. It is standardized with a precisely prescribed form and given standardized instruction for administrator as well a precisely given place for the child´s drawing.

2.3. Data Analysis

The analysis of the obtained data was processed by IBM–SPSS Statistics programme ver. 23. We used the Mann–Whitney U test for comparison of two independent samples because of a low number of participants for parametric tests in the two comparative samples (groups). We used also the Spearman correlation test for identification of relation between tests results: Goodenough intellectual/conceptual maturity, Jirásek test of school maturity–subtest of human figure drawing, Krogh test of school maturity–subtest of human figure drawing.

3. Results

From the results of the implemented stimulation programmes for development of intellectual abilities and empirical cognition, we deduce the following hypotheses:

Hypothesis 1 (H1): We predict that the group of preschool-age children (EG—experimental group) participating in the stimulation programme will show statistically significant intellectual maturity in comparison with control group (CG) not participating in the programme.

The results of statistical testing of empirical cognition on overall intellectual maturity are presented in Table 1. No statistically significant difference between control and experimental group in the test of intellectual maturity occurred.

Hypothesis 2 (H2): We predict that the group of preschool children (EG) participating in the stimulation programme will show statistically significant results in intellectual/conceptual maturity (subscore of content elaboration) in comparison with the non-participating group (CG).

The results of statistical testing of empirical cognitive stimulation programme on subscore of content elaboration are presented in Table 1. No statistically significant difference in intellectual/conceptual maturity between experimental and control group–subscore of content elaboration occurred.

Hypothesis 3 (H3): We predict that the group of preschoolers participating in the stimulation programme (EG) will show statistically significant difference in comparison with non-participating children (CG) in intellectual/conceptual maturity–formal elaboration.

The results of statistical testing of stimulation programme of empirical cognition on subscore of content elaboration are presented in Table 1. No statistically significant difference in intellectual/conceptual maturity between experimental and control group–subscore of formal elaboration in the test of intellectual maturity occurred.

Table 1. The results of statistical testing of empirical cognitive stimulation programme.

	Experimental Group (*n* = 28)		**Control Group (*n* = 22)**		***U***	***P***
	MD	***SD***	***MD***	***SD***		
overall intellectual maturity	17.50	4.97	18.50	4.69	355.500	0.352
subscore of content elaboration	9.00	2.14	9.00	2.44	365.500	0.256
subscore of formal elaboration	8.50	2.92	9.00	3.53	314.000	0.515

In the following part, we present the results of investigation of relation between drawing tests standardly used for orientation measurement of general intellectual/rational level of the preschool child.

Hypothesis 4 (H4): We predict a statistically significant relation between evaluation of intellectual maturity and school capability (Goodenough Draw-a-Person Test and Test of school maturity by Krogh–subtest: Drawing a figure).

The results of correlation analysis were statistically significant and had medium–high positive relation between both tests (see Table 2).

Table 2. The results of correlation analysis.

	r_s	p	N
between Goodenough Draw-a-Person test and test of school maturity by Krogh	0.630	<0.001	50
between test of school maturity by Jirásek and test of school maturity by Krogh	0.631	<0.001	50
between the drawing test of intellectual/conceptual maturity by Goodenough and test of school maturity by Jirásek	0.782	<0.001	50

Hypothesis 5 (H5): We predict that there is a statistically significant relation between evaluation of school maturity and capability (Test of school maturity by Jirásek–subtest drawing a figure and Test of school maturity (capability) by Krogh–subtest drawing a figure).

The results of correlation analysis were statistically significant and showed a medium–high positive relation between both tests (see Table 2).

Research question 1 (RQ1): Is there any statistically significant positive correlation between the drawing test of intellectual/conceptual maturity by Goodenough and test of school maturity by Jirásek?

The results of correlation analysis were statistically significant and showed a strong positive relation between both tests (see Table 2).

The results of particular subscores of the drawing test of intellectual/conceptual maturity by Goodenough (a content and formal elaboration) and test of school maturity by Jirásek were statistically significant and showed a medium–strong positive correlation (see Table 3).

Table 3. The results of particular subscores of the drawing test of intellectual/conceptual maturity by Goodenough and test of school maturity by Jirásek.

	r_s	p	N
a content elaboration	0.668	<0.001	50
a formal elaboration	0.695 **	<0.001	50

Note: **—statistically significant result.

Research question 2 (RQ2): Are percentage results of chosen drawing elements similar to results of Thomazi statistical study?

(a) Front pose of a human figure,
(b) Extremities displayed by line,
(c) Correct arms/hands connection to torso,
(d) Sisplay of arms.

The images of extremities of 5–6 year-old children were compared with Thomazi statistical study [24]. Another assessed parameter was the place of arms connection to figure. In the Thomazi sample, 33% of children had this connection correct. Our research sample had similar results—28% of children connected arms correctly. Thomazi says that all children at the age of 5 to 6 years old in the statistical study displayed the figure from the front. The last characteristic was the drawing of arms on the human figure. In Thomazi's research sample, this was so only in 4.3% of all drawings, but our participants managed to do it correctly in as many as 26% of drawings.

The results show that evaluation of drawing in the above-mentioned tests and indicative level of intellect, perception, and motor maturity are closely connected.

4. Discussion

In H1, H2, and H3, we assume the impact of our stimulation programme developing intellectual/conceptual maturity of preschool-age children. The reasons that the hypotheses were not confirmed in our research study may be due to various factors, such as the chosen variable, or measuring test (which did not display the changes in the intellectual area adequately). Although, according to Valovičová and Sollárová [27], empirical cognition develops logical thinking in the sense of analogy, analytic-synthetic, inductive and deductive thinking, thinking operations such as abstraction, concretization, generalization, analysis and synthesis of systems, and methods of problem solving, intellectual/cognitive processes show significant correlation. However, they are not their correct equivalent [38].

The Goodenough test and all of its equivalents are used for survey of intellectual/conceptual maturity. The question is whether the drawings sufficiently refer to these constructs. The test focuses on monitoring specific functions connected to drawings—perception, imagination, motor activity, and coordination between eyes and hands, which are assessed for mental processes, such as analysis and abstraction [29].

Now, there is the question of selection of intellectual abilities with specific variables, of which the developing effect of the mentioned programme will be displayed, or measurements by different type of tests, e.g., Wechsler intelligence scale for preschoolers [33] (measures intelligence level in various subtests, which can reveal mentioned differences). This measures the level of intelligence in the verbal section: Information, dictionary, understanding, similarities, arithmetic, remembering sentences, and memory. In the nonverbal section are cubes, labyrinth, jigsaw puzzles, coding, and geometry.

The Goodenough test is used to determine aspects such as evaluation of general intellectual functions as a part of evaluation of intellectual ability (talent) and help to discover later cognitive difficulties with learning. It can be used in education and informs about the effectivity of educational activities; stimulation programmes belong to this category, too.

Third, and not a negligible factor for interpretation of our obtained results, can be a long-term discussion about the stability of intellectual abilities. The important factor connected to stability to be mentioned here is the age of participants. Generally, it is proven that the stability is higher as the child is older [34]. The average age of our research sample was 5.58 years in the experimental group and 5.31 years in the control group. The research shows that it is possible to consider the stability of intellectual abilities tests to be very high at the age of 10 and older [35]. Up until then, the values can be unstable, so it cannot be considered as stable until the age of 7 [36].

According to research of Pianta and Egeland [37], the influences of non-stability of intelligence abilities tests is different between the age of 2 and 8 years. The mother's social support and interactive behaviour has an important impact, too.

Theoretical reason for the discovered differences between Thomazi's results and our results could be explained by an impact of the stimulation programme focused on empirical cognition of preschool children. "The result is learning product, knowledge is the form of the most realistic picture of the object of knowledge" [26]. Manifestation of this fact could be proven by drawing arms and correct connections of arms to human figure.

5. Conclusions

In spite of the fact that the first part of our paper—verification of stimulation programme impact developing empirical cognition in preschool-age children on intellectual abilities—intellectual/conceptual maturity was not proven, it does not mean that it has no impact on other psychological variables. Such results can be inspirational for further research; for example, research on the impact of intellect on limited ability (logical–mathematical abilities, analytical intelligence according to Sternberg [38], etc.). We also emphasize the drawing test e.g., correct connections of arms and its image, which showed such differences in comparison with other research. For further research of stimulation programme impacts on empirical cognition, we suggest the increase of the number of participants and the use of various tests for measurement of intellectual abilities.

The analysis of the second part of our programme proved the validity of the tests using the drawing of the man to measure various psychological variables—intellectual/conceptual maturity, school maturity, and school capability. For further research, we recommend verifying other/different psychometric variables of selected tests. Alternatively, we can spread variables to present a relation with a tested variable.

The prepared and implemented programme focuses on empirical cognition and its impact on intellectual abilities—intellectual/conceptual maturity of preschool-age children (5–6 years old) in the educational topic Human and Nature of pre-primary education in the Slovak educational system. It pointed out the importance of natural scientific cognition in the conditions of nursery school. The results of our research can be implemented in designing further stimulation programmes.

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