The New Educational Review

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Effects of an Empirical Cognition Development Programme on the Creative Thinking of Preschool Children

DOI: 10.15804/tner.2020.60.2.07

Abstract

Inquiry-based education as a means of teaching has not been sufficiently studied in the context of empirical cognition in children of lower ages. The currently enhanced space for preschool science education creates possibilities to verify the applicability of physical experiment in the empirical cognition of preschool children and its effect on the development of their creative thinking. The developed Empirical Cognition Development Programme was implemented in kindergarten conditions and empirically verified in a quasi-experimental design on a sample of 102 children (2 experimental groups N = 71; 1 control group N = 31). To capture the level of creative thinking and its changes in children, the Torrance Figural Test of Creative Thinking (Torrance, 1974; Jurčová, 1984) was used. Results of comparative analyses showed a statistically and practically significant increase in the level of the creative thinking factors studied (fluency, flexibility, originality) in one of the experimental groups in comparison with the control group. The article discusses the results and implications for educational practice in the conditions of preschool education.

Key words: *empirical cognition, inquiry-based teaching, physical experiment, pre-primary education, Empirical Cognition Development Programme, creative thinking*

Introduction

Empirical cognition and inquiry

Empirical (experiential) cognition is one of the sources of knowledge. It holds for physics that quantitative and qualitative empirical data are obtained by empirical methods of cognition - observation, measuring and experimentation (Koubek, 1984). Empirical, known also as heuristic, cognition, is included in the strategies called for in creative thinking and in personal experience when seeking explanations of tasks. Koubek (1984) characterizes the *strategy of empirical cognition* as applicable to pupils´ experimental activities in a logical sequence of activities, as follows:

A. Cognitive mental preparation (motivation for learning → discovering and formulating the problem → generating hypotheses → mental experiment);
B. Cognitive material implementation (planning material implementation → selecting material resources → assembling and verifying the apparatus → obtaining empirical data)
C. Cognitive mental processing (processing data outcomes → formulating conclusions → formulating and classifying the piece of knowledge → motivation for further cognition).

It is the deeper understanding of physical phenomena that inquiry-based activities associated with pupils' experimental activities contribute to.

Inquiry-based science education is an approach in teaching, a strategy to manage pupil learning activities, that can be applied in the natural sciences and the arts. It is an intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations and researching conjectures, searching for information, constructing models with peers and forming coherent arguments (Linn, Davis, & Bell, 2004). The European Commission's report " Science Education Now: A Renewed Pedagogy for the Future of Europe" (Rocard et al., 2007) emphasizes and includes science as inquiry and by inquiry as crucially important goals in education. Inquiry-based learning has become officially supported in many countries as pedagogy aimed at improvement of science learning (Bybee, 2000). The current situation is that successful inclusion of inquiry-based education into the practice of a teacher requires further research, mainly on the conditions that facilitate it.

Support of Creative Thinking by Deliberate Educational Efforts

In the research literature dealing with creativity in education, two orientations have attracted special attention: teaching creatively and teaching for creativity. The former is teacher-oriented, while the latter is oriented rather towards increase of creativity in general and related to enhancement of creativity in pupils. When examining relationships between the two orientations, several authors (e.g. Jeffrey & Craft, 2004; Karwowski, 2006) conclude that both are closely related to the effect that teachers teaching for creativity also teach creatively.

Outcomes of the 2009 review made in the European Year of Creativity and Innovation (Ferrari et al. 2009) provided starting points for creative learning and innovative teaching for the well-being of an individual and society. The report credited the key role in this task to education, with one of four reasons for the need to develop children's creativity and innovativeness being that creativity, as a form of knowledge creation for all, supports and enhances life-long skills and competences, with educators able to unlock and foster children's creative potential. The report concluded that creative learning requires innovative teaching.

The responsibility of school and teachers is frequently emphasized within environmental/social factors influencing the development of creativity (e.g. Sternberg & Lubart, 1993), with one of the typical strategies being a deliberate educational effort typically conceived in the form of targeted development stimulation programmes/interventions.

Foreign as well as Slovak researchers working with deliberate stimulation of creativity in children and pupils report empirical findings which confirm that creativity can be developed and promoted in the process of education, not only by the personality of the teacher and pupil, but also by specific tasks and situations (Kaliská, 2015). The design and implementation of programmes stimulating cognitive development and creativity in pre-school children has a long tradition in Slovak conditions. Results of verification of their effectiveness (Sollárová, 1998) provide overall empirical evidence of their effects on the parameters of creativity studied, as well as on other cognitive, social and motivational variables.

Development of Empirical Cognition in Children in Pre-primary Education

Currently science education in kindergartens in the Slovak Republic is regulated by the National Educational Programme ISCED 0 - Pre-Primary Education as the main curricular document. It contains standards (content and performance-related), i.e. requirements for knowledge, skills, capabilities and attitudes arising from the curriculum and defined as the basics. Science capabilities possible to develop at pre-school age include observation (intentional acquisition of new information from environment), classification (comparison and sorting based on intentional observation) and empirical communication (expressed by argumentation, based on personal experience) (ŠVP, 2016). The given context provides a basic framework for seeking the application of theoretical and methodological understanding of *inquiry-based education* also in the conditions of pre-primary education, with the key conceptual and methodological application of *physical experimentation* as the basic form for learning about the physical world, serving as a means for creation of of knowledge about certain physical phenomena, and leading to creation of children's / pupils´ new knowledge. It is in the process of *experimental inquiry-based activities* that pupils can demonstrate their understanding of physical knowledge.

For designing links between curricular content and teaching methods or strategies relevant to inquiry-based education, Williams´ (1972) Cognitive-affective interaction model (CAI) is inspiring, with its *dimension of teaching strategies relevant to methods of creative problem solving.* Cognitive indicators of creative thinking that can be thus stimulated in pupils include fluent, flexible and original thinking. According to Williams (ibid.), fluent thinking is developed by tasks generating quantity of ideas, e.g. the pupil has to name as many objects as possible, with the relevance of his/her answer observed. Flexible thinking is characterized by heterogeneity of ideas and the task for the pupil in developing such thinking could be to use different perspectives in solving a problem. Original thinking is characterized by unconventional answers and it can be developed by assignments which create new, unconventional standpoints.

To anchor the introduction of the research subject, it can be concluded that it appears relevant and applicable in the context of the current framing of science education in pre-primary education to conceive educational activities with characteristics of inquiry-based education, with the key application of physical experimentation as the tool for learning about and understanding physical phenomena, and with teaching strategies using creative problem solving procedures (e.g. the CAI model, Williams, 1972).

Research focus

The above background led the authors of the contribution to draw up an original programme aimed at the development of empirical cognition in preschool children, using strategies and methods of inquiry-based teaching, physical experimentation and strategies using creative problem solving by the specific CAI model (Williams, 1972). The programme thematically focusing on 3 areas (solid, liquid and gaseous substances) was implemented in kindergartens with the **aim** of verifying its effectiveness in several variables (for results of the pilot verification see Valovičová & Sollárová, 2016; Valovičová et al., 2019). The article presents verification of the programme effects on selected indicators of creative thinking.

Research methodology

Background to the research

With the aim to verify the applicability of physical experimentation in the development of empirical cognition in inquiry-based teaching, the Empirical Cognition Programme was conceived for preschool children, with its content devoted to the themes of solid, liquid and gaseous substances (more details in Valovičová, Sollárová, 2016; Valovičová et al., 2019). The programme was aimed at the development of empirical cognition and cognitive abilities in children, using strategies of creative solutions (by the CAI model, Williams, 1972) and the conception of empirical cognition stages (Koubek, 1984).

Research sample

The programme was implemented during the academic year 2017–2018 (experimental group 1, N = 35) and 2018–2019 (experimental group 2, N = 36) in two kindergarten classes in Nitra, with children of pre-school age (5 to 6 years old), during a period of 45 minutes a week during the whole school year. The control group consisted of one class (N = 31).

Research problem

The research problem was defined as investigation of possible intentional support of empirical cognition in science by means of inquiry-based strategies, physical experimentation and using strategies of creative problem solving in the conditions of pre-school education. The investigation also concerns whether the programme as conceived and applied would result in an increased level in children's creative thinking as an effect of planned, targeted stimulation.

Evaluation of the summary effect of the programme was designed as a longitudinal quasi-experiment, with pre-test and re-test measurements in the experimental and control groups; data were processed using standard procedures of comparative analyses.

Research hypothesis

The basic hypothesis was conceived as the assumption that the level of children's creative thinking would increase (in the factors fluency, flexibility and originality) under the influence of application of the Empirical Cognition Programme, significantly more in comparison with children not participating in the programme.

Many researchers have found that creativity development by means of science activities has an influence on the increase of specific factors of creativity (Mirzaie et al., 2009). Education strategies of the programme developed were loaded with many of the creative problem-solving strategies as conceived by Williams in the CAI model (1972).

Instrument and Procedures

With the aim of verifying the effect of the Empirical Cognition Programme on the development of creative thinking indicators in the conditions of pre-primary education, the Torrance Figural Test of Creative Thinking (Torrance, 1974; Slovak version by Jurčová, 1984) was applied in order to capture the level and the changes of factors of creative thinking. The figural form consisted of three drawing activities in three sub-tests (Picture Construction, Incomplete Figures and Repeated Figures). The fluency score was made up of the summary score of the total number of relevant solutions in sub-tests 2 and 3. The flexibility score was composed of the summary score of the total number of solutions of various quality to the stimuli in sub-tests 2 and 3. The originality score was made up of the total score of original (infrequent and imaginative) solutions in all three sub-tests of the test. For the purpose of evaluation of originality, research sample norms were developed of the frequencies of solutions to stimuli in all of the sub-tests.

Results of the research

Table 1. Descriptive indicators of creativity variables and analysis of pre-test/ post-test diferences in the experimental and control groups

Group	Variable	Min	Max	AM	SD	Med	Skew	Kurtosis	Z	r_m
ExG1 (N=35)	Fl_tot_pre	0	26	12.97	6.75	12.0	.22	-.74	2.11 *	-.25
	Fl_tot_post	0	25	10.40	6.73	10.0	.35	-.12		
	Fx_tot_pre	0	22	10.46	5.84	9.0	.39	-.67	**3.10** **	**-.37**
	Fx_tot_post	0	18	7.60	4.70	8.0	.09	-.20		
	Or_tot_pre	0	28	8.09	6.67	6.0	1.27	1.67	**2.87** **	**-.34**
	Or_tot_post	0	46	13.71	10.21	13.0	.86	1.55		
ExG2 (N=36)	Fl_tot_pre	0	20	7.64	5.05	9.0	.09	-.01	**3.80** ***	**-.45**
	Fl_tot_post	0	26	10.67	7.02	10.0	.29	-.23		
	Fx_tot_pre	0	13	5.61	3.69	6.0	-.16	-.77	**2.98** **	**-.35**
	Fx_tot_post	0	20	7.11	4.76	8.0	.45	.59		
	Or_tot_pre	0	14	2.39	3.28	1.5	1.86	1.85	**3.43** ***	**-.40**
	Or_tot_post	0	17	4.67	4.40	4.0	1.06	.94		
ContG (N=31)	Fl_tot_pre	0	17	5.87	4.54	5.0	.51	-.09	.65	-.08
	Fl_tot_post	0	14	5.87	4.24	6.0	.16	-1.0		
	Fx_tot_pre	0	14	4.29	3.81	4.0	.84	.09	1.01	-.13
	Fx_tot_post	0	11	3.68	3.28	3.0	.58	-.56		
	Or_tot_pre	0	14	4.10	4.08	4.0	.78	-.27	**2.30** *	**-.29**
	Or_tot_post	0	25	7.32	6.63	6.0	1.04	1.05		

N – Total number; ExG1 – Experimental group 1; ExG2 – Experimental group 2; ContG – Control group; Fl – fluency; Fx – flexibility; Or – originality; tot-pre – total score, pretest; toto-post – total score, posttest; AM – Mean; MD – Median; SD – Standard deviation; Z – Wilcoxon rank test resulting value; r_m *– effect size value*

The non-parametric Wilcoxon rank test showed a statistical and effect size moderate significance in the experimental group 2 in favour of total scores in fluency, flexibility and originality in the second measurement.

Statistically significant and moderate differences showed in the experimental group 1 in the overall level of Flexibility to the disadvantage of the second testing, however in favour of the second measurement in the variable Originality.

A statistically significant change in Originality was recorded in the control group after 10 months, but of only a low effect size significance.

Table 2. Analysis of differences in the level of creativity components in the control group against two experimental groups before and after application of the programme (ContG vs. ExG1; ContG vs. ExG2)

Variable	Group	AM	SD	Med	Z	r_m
Fl_tot_pre	ContG	5.87	4.54	5.0		
	ExG1	12.97	6.75	12.0	**4.45*****	**-.55**
	ExG2	7.64	5.05	9.0	1.74	-.21
Fl_tot_post	ContG	5.87	4.24	6.0		
	ExG1	10.40	6.73	10.0	**2.88****	**-.36**
	ExG2	10. 67	7.02	10.0	**2.99****	**-.37**
Fx_tot_pre	ContG	4.29	3.81	4.0		
	ExG1	10.46	5.84	9.0	**4.51*****	**-.56**
	ExG2	5.61	3.69	6.0	1.70	-.21
Fx_tot_post	ContG	3.68	3.28	3.0		
	ExG1	7.60	4.70	8.0	**3.45*****	**-.43**
	ExG2	7.11	4.76	8.0	**3.12****	**-.38**
Or_tot_pre	ContG	4.10	4.08	4.0		
	ExG1	8.09	6.67	6.0	**2.76****	**-.34**
	ExG2	2.39	3.28	1.5	1.85	-.23
Or_tot_post	ContG	7.32	6.63	6.0		
	ExG1	13.71	10.21	13.0	**2.90****	**-.36**
	ExG2	4.67	4.40	4.0	1.57	-.19

N – Total number; ContG – Control group; ExG1 – Experimental group 1; ExG2 – Experimental group 2; l – fluency; Fx – flexibility; Or – originality; tot-pre – total score, pretest; toto-post – total score, posttest; AM – Mean; MD – Median; SD – Standard deviation; Z – Mann-Whitney U-test resulting value; p = significance; r_m *– effect size value*

The non-parametric Mann-Whitney U-test for two independent samples showed a high statistical, as well as high practical, significance of differences in creativity variables between experimental group 1 and the control group in all creativity components, in favour of the experimental group l, whether before or after application of the development programme.

In the experimental group 2, the overall level of Fluency and Flexibility changed significantly, as well as moderately significantly based on the effect size value, against the control group after application of the programme.

Discussion

The analysis of the pre-test/post-test differences in the experimental groups and in the control group (Table 1) showed a statistically, with effect size value significant, moderate increase in the level of the creative thinking factors studied (fluency, flexibility, originality) in Experimental Group 2 after participation in the Empirical Cognition Programme, which supports the assumption of a positive influence of the stimulation programme on children's creative thinking. Results in Experimental Group 1 were unambiguous in terms of the assumption only for the factor of originality, with a significant and moderate decline observed in the factor of flexibility. In the control group no significant change was observed in two of the factors studied (fluency, flexibility) but there was a significant increase, at the level of low effect size value significance, in originality.

The analysis of mean input (pre-test) values of the factors studied in the groups studied showed that mean values in all factors were considerably (about twice) higher in Experimental Group 1 in comparison with the other groups, which could explain the decline in this group's flexibility values in the second measurement. Another explanation could be test administration by teachers in the first year of the experiment, who failed to consistently observe time limits for solving individual sub-tests, which enabled children to solve more stimuli in sub-tests 2 and 3, thus not only increasing their fluency scores, but also increasing the likelihood of higher scores in flexibility and originality. That was also why we decided to administer the test ourselves and to ensure the same conditions for the groups tested in the following academic year when the programme was implemented in Experimental Group 2. The considerably and significantly different input values (pre-test) in individual groups inspired us to verify the hypothesis also by analysis of differences in the level of creativity factors in the control group against both experimental groups before and after the application of the Empirical Cognition Programme (Table 2). Comparison of the control group with Experimental Group 2 in all the creativity factors studied showed a comparable (without statistically significant differences) initial level (pre-test) in all factors, but a significantly higher level in Experimental Group 2 in the factors of fluency and flexibility in the second measurement (post-test) in comparison with the control group. No such result showed for originality. This, however, is attributed to the initial value of originality in Experimental Group 2 which was much lower (twice the difference in the value), in comparison with the control group while comparison of pre-test and post-test measurement of originality in the experimental group 2 (Table 1)

appeared statistically, with effect size value significantly higher after participation in the programme.

Both analyses allow us to presume that the results, especially of the first (pre-test) measurement in Experimental Group 1, may be a consequence of test administration conditions - the exceeded time limit for solution of individual sub-tests. The re-test measurement in Experimental Group 1 showed a decline of values in fluency and flexibility, which could be attributed to the relatively late timing of the measurement just before the holidays, which could have led to children having poor motivation to solve the test tasks. The subsequent change in administration and timing of the re-test measurement for Experimental Group 2 will be further verified.

Conclusions

The results of the study contribute to the investigation of pre-school children's empirical cognition and appear to support inquiry-based teaching as a means of teaching also in conditions of pre-school education.

Development and implementation of the authentic, original programme aimed to foster empirical cognition in pre-school children using physical experimentation, conceived as creative problem solving and inquiry-based learning, and brought valuable knowledge which is applicable in the practice of pre-school science education.

Through evaluation of the effectiveness of the developed and implemented programme with regard to variables loading on the creative thinking of children, the contribution meets methodological standards for development and application of intervention programmes based on research evidence.

Acknowledgements
The contribution is part of the project VEGA 1/08/15/18

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