The New Educational Review

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An Example of Integrated Teaching of Mathematics and Environmental Education in the Second Grade of Basic School

DOI: 10.15804/tner.2015.41.3.01

Abstract

On the basis of research and the syllabi for mathematics and environmental education, which promote integrated teaching, a model of integrated teaching of mathematics and environmental education has been designed. 331 basic school second grade pupils participated in the experiment (163 pupils in the experimental group and 168 in the control group). The differences in the results were statistically significant after the second test, as compared to the control group, the experimental group performed better at all levels of TIMSS taxonomy. With this the importance of interdisciplinary integration or of holistic teaching, indispensable in the first years of schooling, was confirmed.

Keywords: *holistic learning, interdisciplinary integration, mathematics, environmental education*

Theoretical foundations

The significance of interdisciplinary integration in school

Interdisciplinary integration is defined as an example of holistic learning and teaching that represents the real interactive world, its complexity, abolishes frontiers between individual subjects and promotes the principle all knowledge is interrelated (Sicherl-Kafol, 2007). The learning process is oriented to learners' active role, it allows them to achieve taxonomically higher learning objectives and encourages a multidisciplinary approach to problem solving while the pupils simultaneously get the feeling of applicability of the acquired knowledge in other subjects as well as in everyday life. Integrating subjects does not imply denying disciplinarity; it rather upgrades it qualitatively. When designing interdisciplinary integrations the goals and didactics of individual disciplinary areas must be respected. Haylock & Thangata (2007) find that there are many teachers who link learning content of different subjects to each other, they are, however, not even aware of these links. The teacher must plan interdisciplinary integration and draw students' attention to the multitude of tiny links between different subjects.

In theory, there are various terms and in consequence also various definitions of interdisciplinary integration (Štemberger, 2007; Skupnjak, 2009; Rutar Ilc & Pavlič Škerjanc, 2010; Ciperle, 2012). Ciperle (2012) thinks the term "interdisciplinary integration" contains the notions of analysis and synthesis. The author explains that it is a characteristic of analysis to decompose a complex whole, dissect and break it down to smaller and smaller elements; while it is characteristic of synthesis to integrate different elements into something new. From this point of view, interdisciplinary integration does not represent an attempt to erase the boundaries between subjects and/or to abolish individual subjects; it rather represents maximum exploitation of every potential resulting from the distribution of the totality of knowledge into individual areas.

In many school systems interdisciplinary integration started with the introduction of flexible timetabling (Finland, Sweden). This is, however, not a limitation for the performance of quality interdisciplinary integration at the school level. For teachers interdisciplinary integration will have to become a meaningful way of teaching in the 21st century.

Empirical part

Research Problem

In today's school, integration of contents and subjects that until now have most often been strictly separated from each other and fragmented is expected to be encouraged. It is exactly this fragmentation we wish to overcome with interdisciplinary integration that allows for more understandable, more useful, and more comprehensive acquisition of learning content and with this, a better quality and longer lasting knowledge. In the 2011 modernisation of syllabi for basic school it was exactly assuring quality and lasting knowledge that the main emphasis was put on. Such knowledge can only be achieved with the contents that are not just useful in one school subject, but are multidisciplinary and require seeking solutions to the problems pupils encounter in life.

The research problem is oriented into designing and evaluating an experimental interdisciplinary model of teaching mathematics and environmental education.

Research Focus

The purpose of our research was to develop and evaluate an experimental model of teaching with the inclusion of interdisciplinary integration with an emphasis on mathematics and environmental education and to describe the procedures for organising and performing concrete interdisciplinary integration.

Research Hypotheses

General hypothesis

The pupils who have been taught with the use of the experimental model of teaching and learning will perform better in solving mathematical and environmental tasks than the pupils who have received traditional teaching of both mathematics and environmental education (with no interdisciplinary integration).

Specific research hypotheses

H1*:* Solving the science and mathematical tasks of the first taxonomic level—**knowledge of facts and procedures** (TIMSS taxonomy), the experimental group will perform more successfully than the control group.

H2: Solving the science and mathematical tasks of the second taxonomic level—**use and understanding of concepts, solving routine problems** (TIMSS taxonomy), the experimental group will perform more successfully than the control group.

H3: Solving the science and mathematical tasks of the third taxonomic level—**drawing conclusions, justifying and analysing** (TIMSS taxonomy), the experimental group will perform more successfully than the control group.

Research Methodology

Basic research methodology and research approach

In the framework of empirical research approach, the educational experiment was applied in the research study, as it is appropriate for teaching novelties being introduced into the teaching of mathematics and environmental education. The *causal-experimental method* was applied. A single-factor model of experiment with school sections as compared groups was designed. The existing sections of the second grades of basic schools were used as compared groups.

The group of pupils that received our teaching was called experimental group (EG) and the group taught in the traditional way by their teachers was called control group (CG).

The experimental factor introduced into the EG was: **interdisciplinary integration of mathematics and environmental education.**

Experiment sample

331 pupils of the second grade of basic school participated in the experiment. The experimental group (EG) comprised 163 pupils, while 168 pupils were included in the control group (CG).

In the experiment, the experimental factor represented the independent variable. There were several dependent variables, as all the variables with which the knowledge of the pupils in the experimental group (EG) and in the control groups (CG) was tested belong here.

The dependent variables are:

- Children's performance in solving science and mathematical tasks at the first taxonomic level—**knowledge of facts and procedures** (TIMSS taxonomy);
- Children's performance in solving science and mathematical tasks at the second taxonomic level—**application and understanding of concepts, solving routine problems** (TIMSS taxonomy);
- Children's performance in solving science and mathematical tasks at the third taxonomic level—**drawing conclusions, justifying and analysing** (TIMSS taxonomy).

Course of the research and gathering data:

Prior to the experiment, the pupils' knowledge was tested with the initial knowledge test. The test was constructed in compliance with the instruction on knowledge testing and according to the TIMSS taxonomy of knowledge. At the end of the experiment the knowledge of the experimental and the control groups was examined with a written test again. The initial and the final knowledge tests consisted of 12 tasks (4 at the first taxonomic level, 4 at the second taxonomic level, and 4 at the third taxonomic level), which the pupils solved in three parts.

Results and Interpretation

The statistical processing was carried out with the assistance of the statistical software package IBM SPSS 22. The differences at the beginning and at the end of the experiment were determined with t-test. The results were interpreted, confirming the set hypotheses. In testing the hypotheses the rule was observed the greatest tolerable risk for the rejection of the hypothesis was 5 %, the selected value of the significance level was thus 0.05.

Analysis of the differences in the knowledge of the pupils in the experimental group (EG) and the control group (CG) at all three taxonomic levels – initial situation

Let us first present the basic statistical parameters of the initial test.

Table 1. The basic statistical parameters of the initial knowledge test with the EG and CG at the first taxonomic level (TL1), at the second taxonomic level (TL2), and at the third taxonomic level (TL3)

	Group	*N*	Arithmetic mean	Performance (in %)	Standard deviation	Min.	Max.
TL1	EG	163	2.43	60.74	0.902	0.00	4.00
	CG	168	2.40	59.97	0.929	0.00	4.00
TL2	EG	163	2.29	57.21	0.973	0.00	4.00
	CG	168	2.33	58.33	0.989	0.00	4.00
TL3	EG	163	2.01	50.30	1.606	0.00	4.00
	CG	168	1.95	48.66	1.631	0.00	4.00

Table 1 shows that in the initial knowledge test there were no noticeable differences between the EG and the CG at any of the taxonomic levels. The average performance (in %) of both the pupils in the EG and in the CG was rather low. The best results were obtained at the first taxonomic level, i.e. in knowing facts, procedures, and concepts. The pupils in the EG obtained 60.74 % and the pupils in the CG 59.97 %. The pupils in the EG and in the CG obtained the lowest results at the third taxonomic level, where justification and drawing conclusions was required. The performance was 50.30 % in the EG and 48.66 % in the CG. In contrast with the performance at the first and at the third taxonomic levels, at which the pupils in the EG performed slightly better than those in the CG, the pupils in the CG performed slightly better (58.33 %) than the pupils in the EG (57.21 %) at the second taxonomic level, where understanding concepts and solving routine problems was required. We explored whether the differences in the performance of the two groups at any of the taxonomic levels were statistically significant with the *t*-test (Table 2).

Table 2. The differences in the knowledge in solving mathematical-science problems between the EG and the CG (*t*-test) in the initial test at the first (TL1), the second (TL2), and the third (TL3) taxonomic levels

	t	Degrees of freedom	The level of statistical significance	The difference between the arithmetic means	Standard error
TL1	–0.304	329	0.761	–0.031	0.101
TL2	0.417	329	0.677	0.045	0.108
TL3	–0.370	329	0.712	–0.066	0.178

The data in Table 2 shows that the differences between the performance in the EG and in the CG are not statistically significant at any of the taxonomic levels, as in all the three cases the level of statistical significance is higher than 0.05. In this way we confirmed that the pupils in the EG and in the DG performed equally at all the three taxonomic levels.

Analysis of the differences in the knowledge of pupils in the experimental group (EG) and the control group (CG) at all three taxonomic levels – final situation

Table 3. The basic statistical parameters of the final knowledge test of the EG and CG at the first taxonomic level (TL1), at the second taxonomic level (TL2), and at the third taxonomic level (TL3)

	Group	*N*	Arithmetic mean	Performance (in %)	Standard deviation	Min.	Max.
TL1	EG	163	2.80	69.94	0.944	0.00	4.00
	CG	168	2.41	60.27	1.029	0.00	4.00
TL2	EG	163	2.50	62.58	0.856	0.00	4.00
	CG	168	2.30	57.59	0.953	0.00	4.00
TL3	EG	163	2.39	59.66	1.513	0.00	4.00
	CG	168	1.93	48.21	1.588	0.00	4.00

Table 3 presents the final situation results, i.e. the results of the final test of knowledge of the pupils in the EG and the CG at all the three taxonomic levels. Differences between the performances of the pupils in the EG and the CG show at all the three taxonomic levels. At the first taxonomic level (knowing facts, procedures, and concepts), the average performance of the pupils in the EG was equal, 69.94 %, and the performance of the pupils in the CG was slightly lower, 60.27%. At the second taxonomic level (the application of knowledge and understanding concepts), the difference in the performance was a little lower (EG 62.58 % and CG 57.59 %). The largest difference (slightly above 11 %) is seen at the third taxonomic level, where the pupils were required to draw conclusions and to justify—the pupils in the EG obtained 59.66% and those in the CG 48.21%. In the final test of knowledge the pupils in the EG achieved higher results than the pupils in the CG at all the three taxonomic levels. To verify whether the difference in the performance of the pupils in the EG and that of the pupils in the CG is statistically significant, *t*-test was applied (Table 4).

Table 4. Representation of the differences in the knowledge of solving mathematical-science problems between the EG and the CG (*t*-test) in the final test at the first (TL1), the second (TL2), and the third (TL3) taxonomic levels

	t	Degrees of freedom	The level of statistical significance	The difference between the arithmetic means	Standard error
TL1	–3.562	329	0.000	–0.387	0.109
TL2	–2.002	329	0.046	–0.199	0.100
TL3	–2.685	329	0.008	–0.458	0.171

Table 4 shows that the level of statistical significance is lower than 0.05 at all the three taxonomic levels. The differences in the performance on the final knowledge test are statistically significant and in favour of the pupils in the EG at all the three taxonomic levels. Thus, the three specific research hypotheses were confirmed.

The pupils who took part in the experimental model of teaching and learning with interdisciplinary integration of mathematics and environmental education were more successful at solving science and mathematical tasks than the pupils who did not participate in this model. They were, thus, more successful at the level of knowing facts and procedures (the first level) as well as at the level of the application of understanding concepts and routine problems (second level), and at the level of drawing conclusions, justifying, and analysing (third level).

In the research study, we proved that the model of interdisciplinary integration of mathematics and environmental education had a positive effect on the knowledge of the pupils in the EG at all the three taxonomic levels. A reason for higher achievement in the knowledge of the EG could also be that the pupils started the classes working outside school, which additionally motivated them and aroused the interest in further work in them. The work with natural materials had positive effects on the understanding of some of the basic mathematical and science concepts.

Environmental education is thus simultaneously the goal and the process; the concepts are shaped gradually and thinking develops. By affecting objects and materials notions emerge about the world in which the child lives. The so-called naïve physics, naïve biology, as well as naïve chemistry develop, which together with the experience in other areas of activities makes up everyday knowledge or so-called common sense. According to common sense, force is needed to start a movement and none is needed to stop it, as the moving objects stop by themselves, as Marjanovič-Umek (2001) finds.

Conclusions

Interdisciplinary integration is important both in the early years of schooling and in later periods, as it represents a good motivational means for learning and contributes to a comprehensive understanding of various school subjects. Performing interdisciplinary integration is especially important in the first educational cycle of basic school, as in this developmental period the child comprehends the surrounding world as a whole. The learning and teaching that is comprehensive and oriented into the pupil's active role allows for attaining higher taxonomic levels of knowledge, which has been proved in our research. We have further proved that pupils who have received interdisciplinary integrated teaching perform better at solving problems, which contributes to strengthening the feeling of applicability of the acquired knowledge, or as Marjanovič-Umek (2001) states, to shaping common sense based on everyday life experience. We have thus been slowly approaching meeting the recommendation of 2003 PISA, which emphasised the significance of assessing life competences gained in different areas of the curriculum (Repež & Drobnič Vidic, 2008).

Several authors, such as Benedict (1991), Marentič Požarnik (1993), Skribe-Dimec (1995), Uzelac & Starčević (1999), Lepičnik Vodopivec (2014), point out that children must be in immediate contact with the environment to be able to develop adequate sensitivity towards the environment and towards themselves. The gained experiences also serve as assistance in the process of shaping a positive attitude towards the environment and towards oneself and in developing attitudes and values.

This is why it has repeatedly been emphasised that the child learns the best in the natural environment and about everything related to this environment. In concrete everyday life, "where everything happens", teachers can get many ideas for various activities that stimulate the development of thinking, speaking, emotions and in the areas of motor, moral and social development (Pišot, 2000). In the first education cycle of basic school it is important for various potentials of individuals to be engaged and developed.

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