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Experimental Textbook for Technical and Natural Science Subjects in the Slovak Republic

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Abstract: The study characterizes the possibilities of proper preparation of an electronic textbook for primary school. It describes a specific process of conducting a pedagogical experiment to verify the textbook in the education. The authors focus on the theoretical basis for creating modern textbooks applied in the teaching of technical and science subjects. There are still no textbooks on technical and science subjects for lower secondary schools in the Slovak Republic. The authors work to create modern print and multimedia textbooks. The study aims at verifying a new electronic textbook and studying its effects on pupils' performance at primary school. The first part of the article describes the characteristics of the textbook; the second part determines research hypotheses tested in practice. The pupils who worked with it have achieved better results. The differences between pupils in the control and experimental groups were statistically significant at all three levels of learning according to Niemierk's taxonomy, which is an important finding. The textbook will contribute to teaching technical and natural science subjects in the Slovak Republic. Pedagogical research has shown that the effective combination of scientific knowledge and illustration in the new textbook contributes to the effective acquisition of new information in education.

Keywords: natural and technical subjects, elementary school, textbook, pupil.

斯洛伐克共和國技術和自然科學學科實驗教科書

摘要：該研究描述了適當準備小學電子教科書的可能性。它描述了在教育中進行教學實驗以驗證教科書的具體過程。作者著眼於創建現代教科書應用於理工科教學的理論基礎。斯洛伐克共和國仍然沒有關於初中技術和科學科目的教科書。作者致力於創建現代印刷和多媒體教科書。該研究旨在驗證一種新的電子教科書，並研究其對小學生成績的影響。文章的第一部分描述了教材的特點；第二部分確定在實踐中檢驗的研究假設。與它合作的學生取得了更好的成績。根據尼米爾克的分類法，對照組和實驗組的學生在所有三個學習水平上的差異在統計上都是顯著的，這是一個重要的發現。該教科書將有助於在斯洛伐克共和國教授技術和自然科學科目。教學研究表明，新教材中科學知識與插圖的有效結合，有助於有效獲取教育新信息。

关键词：自然和技術科目，小學，教科書，學生。

1. Introduction

The content of the subject matter is enriched by information connected to the relation of man to work, with the need to acquire basic work skills and habits in different work areas [1]. Education in this area is heading towards creating and developing key competencies of pupils by leading them to objective

learning of their surroundings, the needed self-confidence, and a new attitude and values concerning the work of man, technology, and the environment. Technical education goals at elementary schools include cognitive, affective, and psychomotor areas, which need to be developed proportionally. Teachers in the educational process manage both technical and

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professional facts and make pupils acquainted with them. To reach the goal, they use appropriate teaching aids, traditional and modern, as necessary. The information age has brought ICT technologies to the educational process, opening new dimensions for it [2]. Computer-aided instruction may change traditional education from the passive acquisition of information into an active discovery. Teachers cease to be only intermediaries of knowledge, but they become managers of the cognitive process of their pupils. Education using new forms with the help of ICT was relevant mainly to universities, which have a modern information infrastructure with quick access to the Internet. Both secondary and elementary schools are beginning to use this type of education increasingly more [3]. Literary teaching aids prepared in an electronic form represent an important element of the system of teaching aids. They represent a primary source of information containing didactically compiled subject matter delimited by the curricula, prepared according to didactic principles [4]. Our scientific study aims to briefly characterize the process of developing an electronic textbook for the "Technology" subject for the fifth grade in lower secondary education. We have also included outcomes of the performed pedagogical experiment focused on verifying an electronic textbook named "Technology for the 5th Grade of Elementary Schools."

2. Brief Characteristic of the Electronic Textbook and Electronic Texts

The electronic textbook has its place in the system of literary teaching aids. Electronic text is an ordered set of understandable signs and format information capturing a string of ideas of its author. It is also very easy to transform electronic texts formally; during such transformation, the sign system changes, but the content does not [5]. Sign systems used by humans in the form of a text, image, sound, and other combinations are automatically transformed into a digital system both when being saved in the computer and when exiting the computer [6]. Data may then be transferred easily and at high speeds from one medium to another (e.g., from a hard disk to a CD-ROM or a flash disk). Programs enabling easy automatic content transformation are gradually developed, e.g., different kinds of text condensation with minimum information losses. Interactivity is demonstrated not only in the possibility of the automatic search for text strings but also in the fact that each reader can work with a document based on the status of their knowledge basis and the choice of process alternatives and the reader has, e.g., a possibility to communicate with the author. In addition, a full-text method (full text, natural language processing) may be used in digitalized texts. Artificial intelligence may be used to recognize objects in digitalized images (e.g., when recognizing objects in aviation images). Electronic textbooks are

characterized by easy and flexible manipulation with data and their files saved in the computer, which is demonstrated in structuring or restructuring text, image, or musical work. Unlike traditional texts that work with one type of data at a time, electronic texts combine text, visual and acoustic data or video sequences and their simultaneous viewing in one device. We also present a sample of teaching materials for technical and science subjects (Fig. 1).



Fig. 1 Sample from the creation of teaching material to an electronic textbook [7]

3. Materials and Methods

3.1. Selection and Characteristics of the Research Sample

When dealing with the topic of the scientific study, the author's goal was to characterize the reasons for developing and the importance of textbooks in technical education at elementary schools. In the empirical part, the authors are focused on the researched topic "To what extent the developed and applied electronic textbook affects pupils when performing better in the cognitive and psychomotor areas." The authors have opted for corresponding methods to help them achieve the set objective. The main methods applied during the review of expert and scientific studies included analyzing the acquired knowledge and the development tendencies in the education system. In a pedagogic experiment, we compared groups of pupils. In one group of pupils, instruction was carried out using traditional methods, and in another group, the instruction was carried out using a developed electronic textbook. A non-standardized didactic test was used to compare the

performances of the pupils. We have designed the didactic test according to Ivan Turek [8]. We have also discovered that the outcomes (pupils' performances) in the control and the experimental groups are different and statistically significant.

3.2. Research Procedure

We tried to determine the extent to which the new Technology textbook will help 5th-grade pupils or influence the degree of their acquired knowledge. Instruction in a control group (C) was carried out in a traditional manner (pupils did not work with the new textbook), and pupils in an experimental group (E) worked with the new textbook. After the end of instruction in the control and the experimental groups, we used a didactic test for both groups at the end of the natural pedagogical experiment. The didactic test was intended for 5th-grade pupils at elementary schools. The didactic test was a non-standardized continuous NR test. We established the following hypotheses:

H_0 : Results achieved in the non-standardized didactic test will be equal in the control and the experimental groups.

H_1 : As a result of an instruction with the new textbook, respondents of the experimental group will perform better in the cognitive area than the control group, where instruction will be carried out using traditional methods without the new electronic textbook.

$H_{1.1}$: We suppose that due to instruction with the new textbook, pupils of the experimental group will perform better in the "remembering" learning level than the control group pupils, where instruction will be carried out without the new electronic textbook.

$H_{1.2}$: We suppose that as a result of an instruction with the new electronic textbook, pupils of the experimental group will perform better in the "understanding" learning level than the control group pupils where instruction will be carried out without the new electronic textbook.

$H_{1.3}$: We suppose that as a result of an instruction with the new electronic textbook, pupils of the experimental group will perform better in the "specific transfer" learning level than the control group pupils

where instruction will be carried out without the new electronic textbook.

The researched sample was composed of 5th-grade pupils of elementary schools. We researched one control group consisting of 300 pupils and one experimental group consisting of 300 pupils. The control and experimental groups represented a sample with 600 pupils. A basic set included 40 elementary schools from all eight regions in the Slovak Republic. By drawing lots, we randomly chose 16 (two schools from each region) elementary schools where the pedagogical experiment was being carried out. Pupils were randomly (by drawing lots) divided into two groups – an experimental and a control group. The control and the experimental groups were equal in terms of the number and the gender of pupils. The pedagogical experiment was conducted in the 5th grade of elementary schools, while none of the pupils had repeated any previous grade, and the pupils were almost the same age.

We focused on the structure of a non-standardized didactic test. We used a cognitive didactic Technology test (after this referred to as "DT") for the 5th grade of elementary schools.

As a second step, we delimited a rough content of the DT. The rough content of our DT is as follows:

- Man and technology;
- Man and production in practice;
- Utility and gift objects.

3.3. Research Results

When preparing the non-standardized didactic test, we followed Ivan Turek's principles [8]. Our aim was that the didactic test covers the inspected subject matter in an even and representative manner, i.e., to achieve the highest content validity of the DT. We analyzed specific goals. In our case, specific goals are subordinated to general educational goals, and they respect the acquisition of key competencies of 5th-grade pupils in technology. We prepared a specification table (Table 1). The specification table determines the content on which the tasks of the DT should focus, their numbers, and levels of acquisition of knowledge according to Niemierko's taxonomy of educational goals.

Table 1 DT specification table

No.	Topics	Total task number		The number of tasks for		
		Absolute	%	Remembering	Understanding	Specific Transfer
1	Man and technology, professions of craftsmen	5	50	2	3	0
2	Product, creation of a simple product	3	30	1	1	1
3	Sketch of a simple product	1	10	0	0	1
4	Technical materials and tools for product manufacturing	1	10	1	0	0
Continuation of Table 1						
Total		10	100	4	4	2

In step IV, we determined the form of DT tasks. We prepared both open and closed tasks for the DT. We prepared open (production and fill-in) tasks with brief answers. Closed tasks were mainly matching tasks and tasks with a selection of correct answers. We proposed different tasks in our DT. When formulating them, we used the following pedagogic documents: textbook, national and school educational program, and written preparations for instruction units. We designed a bank of tasks for the DT, from which we chose ten tasks for DT. We opted for 10-minute test duration. Pupils had the least time for tasks where correct answers were to be selected. Tasks in which pupils were adding (creating) answers were most time-consuming. For these tasks, we increased the necessary test time to 1-2 minutes. We prepared two variants of DT tasks with different sequences of the tasks. We assigned weights of significance to the tasks, which may be seen in Table 2. DT tasks are assigned weights of significance because not all tasks are always equal. It is always more valuable to understand something than only to remember it, and it is even more valuable to apply what has been learned than to understand it. We consider such differences when allocating the weights of significance. Tasks in the DT based on 3 levels of acquisition of subject matter, solved only by remembering something, have been assigned the weight of significance 1, tasks with understanding have received the weight 2, and tasks focused on a specific transfer have been given the weight 3.

Table 2 Weighing DT tasks

Learning level	Remembering	Understanding	Specific transfer	Non-specific transfer
Weight of significance	1	2	3	4
Task No.	1, 4, 9, 10	2, 3, 5, 6	7, 8	-

Since our DT contained fewer than 20 tasks, we proposed a comprehensive scoring of tasks in the DT. Table 3 contains a detailed analysis of DT scoring.

Table 3 DT scoring

Task	Number of /scored/ points	Description
1	0.5	0.5 points for the correct answer
2	1	1 point for the correct answer.
3	1	1 point for the correct answer.
4	0.5	0.5 points for the correct answer.
5	4	0.5 points for each correct answer, max: 4 points.
6	2	1 point for correctly matching the answer, max: 2 points.
7	3	1 point for each correct answer, max: 3 points
8	3	Max. 3 points for drawing a correct sketch.
9	0.5	0.5 points for the correct answer.
10	0.5	0.5 points for the correct answer.

Table 4 Basic (descriptive) statistics

Variables	Control group	Experimental Group
Valid data	300	300
Sum	3,032 1	3,812
Mean	10.106667	12.706667
Variance	5.145775	6.789922
Standard deviation	2.26843	2.605748
Upper 95% CL of mean	10.364402	13.002728
Lower 95% CL of mean	9.848931	12.410606
Maximum	16	16
Upper quartile	11	15
Median	19	14
Lower quartile	9	11
Interquartile range	2	4
Minimum	4	7
Range	1162	9
Centile 95		16

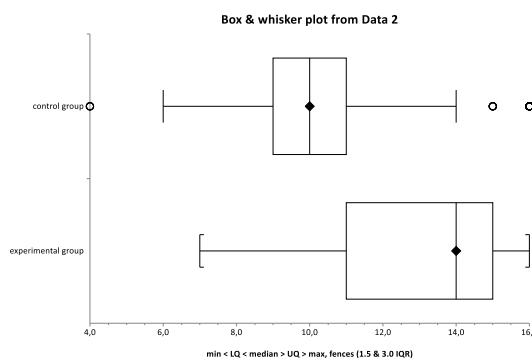


Fig. 2 Median, quartile, and variation range of the variables from the exit test in the 5th-grade

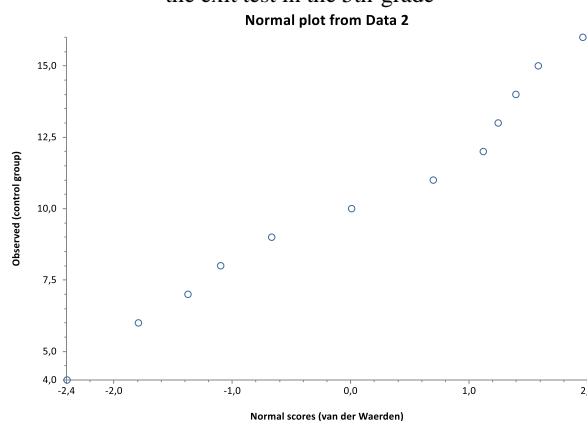


Fig. 3 Assessing the normality of accidental errors – chart of normality of residues in the control group

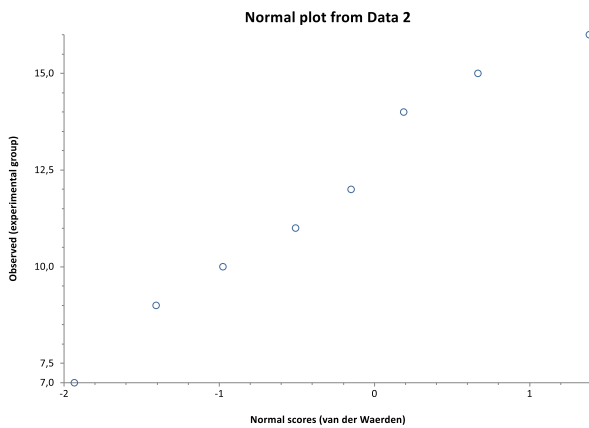


Fig. 4 Assessing the normality of accidental errors – chart of normality of residues in the experimental group

The below-stated text contains a calculation and a finding of statistically significant differences in performances of pupils of the control and the experimental groups and performances of pupils of the control and the experimental groups at the remembering, understanding, and specific transfer learning levels.

Table 5 Kruskal–Wallis test (total performances of pupils)

Kruskal–Wallis Test

Variables: control group, experimental group

Groups = 2

df = 1

Total observations = 600

T = 135.169201

P < 0.0001

Adjusted for ties:

T = 138.111137

P < 0.0001

Table 6 Kruskal–Wallis test (performances of pupils at the "remembering" learning level)

Kruskal–Wallis Test

Variables: Control (remembering), Experimental (remembering)

Groups = 2

df = 1

Total observations = 600

T = 34.756023

P < 0.0001

Adjusted for ties:

T = 37,040276

P < 0.0001

Table 7 Kruskal–Wallis test (performances of pupils at the "understanding" learning level)

Kruskal–Wallis Test

Variables: Control (understanding), Experimental (understanding)

Groups = 2

df = 1

Total observations = 600

T = 36.473363

P < 0.0001

Adjusted for ties:

T = 37.802138

P < 0.0001

Table 8 Kruskal–Wallis test (performances of pupils at the "specific transfer" learning level)

Kruskal–Wallis Test

Variables: Control (spec. transfer), Experimental (spec. transfer)

Groups = 2

df = 1

Total observations = 600

T = 92.974445

P < 0.0001

Adjusted for ties:

T = 96,583817

P < 0.0001

We wished to know the performances of pupils in the didactic test. If they correctly filled in the 5th-grade didactic test, 5th-grade pupils could be awarded the highest gross score (GS) of 16 points. It is obvious from the descriptive statistics (Table 4) that 5th-grade pupils of the experimental group mastered the subject matter more successfully than pupils of the control group. The calculated arithmetic average and the standard deviation were calculated in the reliability interval: lower interval: -95%, upper interval +95%. We may conclude from the average acquired from the measured researched sample that the calculated arithmetic mean for the experimental group is from the measurement reliability interval 12.41-13.00, and for the control group – 9.85-10.36. We have also found that deviations of values from means are not so high, so we may state that the arithmetic means are most valid. The variation range is from 4 (minimum value) to 16 (maximum value). Table 4 shows that the minimum score awarded in the didactic tests for the 5th grade was 4 points, and the maximum score was 16 points. The median calculated for the control group was 10 and for the experimental group 14. That is to say, half of pupils in the control group scored ≤ 10 points in the DT, and the other half of pupils scored ≥ 10 points in the DT. Half of pupils scored ≤ 14 points in the experimental group in the DT, and the other half scored ≥ 14 points in the DT. Based on the descriptive statistics, we may also state that the sharpness coefficient is not equal to zero, and we, therefore, conclude that the distribution of values is sharper (asymmetric) than the standard distribution of values.

We may also see in Fig. 1 that the results achieved in the experimental group were better than in the control group. It is obvious from Fig. 1 that the mean value of the set is equal to 10 in the control group and 14 in the experimental group. The median is the mean value that divides a relevant sequence of values into two approximately identical halves. In the case of systemic division of values, the median is equal to the mean. In our case, we have found out that the calculated arithmetic mean and the median is not equal. We have measured a higher deviation of the median from the mean in the experimental group. The quartile range represents the area of mean 50% of values of the variables, i.e., from 6 to 14 in the control group and from 7 to 16 in the experimental group. It represents a difference between the third and the first quartile (75th and 25th percentile). The quartile range is important for determining the so-called outliers. In our case, we

have found out that there are few outliers beyond the (quartile range) interval in the researched set.

We analyzed the values to find out if such outcomes are statistically significant. To choose a correct analysis of values, we had to examine the assumption of the standard distribution of likelihood of random errors first. We examined the assumption of the standard distribution of likelihood of random errors using normality charts (Fig. 2, Fig. 3) and comparing variances of basic sets. The charts (Fig. 2, Fig. 3) are not symmetric, and the calculated variances are not equal either. The residuum is the difference between an actual and an estimated value. In our case, residua have no standard distribution because the residua normality chart did not form a line, or, in other words, the form of standard likelihood charts is not acceptable (Fig. 2, Fig. 3). Fig. 2 and Fig. 3 indicate that the assumption of the standard distribution of the basic set was not correct. Based on the discovered facts, we decided to use a non-parametric Kruskal–Wallis test to find statistically significant differences between the control and the experimental groups. Since we compared the results of pupils from the control and the experimental groups, we are verifying the validity of the zero hypothesis by analyzing the variance (using a non-parametric test, more particularly). We compared the results on the significance level of $\alpha=0.05$. The significance level is an expected likelihood of rejecting the zero hypothesis, which we have determined before. In our case, the **p**-value (calculated value) is the lowest likelihood for rejecting the zero hypothesis determined based on selective findings. Therefore, we identify the two values with different symbols. How we may decide about the test result is to compare the p-value and α significance level. The following rule applies:

For the particular α significance level:

- 1) We are rejecting the zero hypothesis if $\alpha \geq p$ -value.
- 2) We are accepting the zero hypothesis if $\alpha < p$ -value.

This form of testing is the fastest and the most comfortable if we have a computer available because most statistical program systems calculate the p-value. In this case, it is enough to compare the p-value with α significance level, which we have determined, and we may decide about the test result very quickly.

In our case, the measured p-value is the lowest likelihood for rejecting the zero hypothesis determined based on selective findings. In our case, the calculated p-value (Table 5) is lower than α value (0.05). The test statistics is in the area of rejecting the zero hypothesis. Therefore, we reject the zero hypothesis and conclude that the results are statistically significant in favor of the experimental group. Such finding is significant at α significance level of 0.05 (95%).

To conclude, we may express the significance of the H_1 hypothesis, i.e., the H_1 hypothesis has been proved correct with the significance level of 0.05 (95%). We

also found statistically significant differences between the control and the experimental groups at the remembering, understanding, and specific transfer learning levels. The calculated p-value (Tables 6, 7, 8) is smaller than α value. We may state that the results are statistically significant in favor of the experimental group at the remembering, understanding, and specific transfer learning levels. Such finding is significant at α significance level of 0.05 (95%). The $H_{1.1} - H_{1.3}$ hypotheses have been proved correct.

4. Discussion

From 1 September 2015, innovative state educational programs started to apply in the regional school system in lower secondary education. The "Technology" subject was also affected by the changes. Since textbooks for the "Technology" subject are still in short supply at elementary schools, we have decided to write an electronic textbook for pupils of the 5th grade at elementary schools as a part of the KEGA project 002UMB-4/2015. The electronic textbook "Technology for the 5th Grade of Elementary Schools" is divided into three areas. The content of each area is composed of basic and extended subject matter. There are revision tasks at the end of each area. The textbook also contains projects which pupils deal with directly during school lessons or as a part of the assigned [8]. A correctly developed electronic textbook gives pupils a free and easy access to information they need. When developing the electronic textbook, we met the below-stated requirements:

- Understandability – the didactic text must be comprehensible;
- Language correctness – all texts were written by us are clear, professional, grammatically and stylistically correct and apposite;
- High creative and graphic level – from the creative and graphic point of view, our texts are appealing, and they enhance the aesthetic sense of pupils;
- Ergonomic requirements – the text and illustrations are designed so that pupils find their bearings easily in the electronic textbook.

5. Conclusion

In general, we may state that textbooks or literary teaching aids have had their justified place in technical education in the current school system. Literary teaching aids are intended for pupils. Teachers use different sources of information to prepare for lessons, e.g., technical literature. Nowadays, electronic textbooks and other electronic texts used in the educational process are very important, particularly thanks to several advantages mentioned above. In our scientific study, we have pointed out the options of developing and preparing an electronic textbook for the "Technology" subject. Technology has its future in the educational process. The "Technology" subject

included in lower secondary education develops pupils' knowledge and skills that are very important and needed for young people to find jobs in the modern information society.

The scientific study brings new findings in the field of research into the creation and application of new textbooks for technical and natural science subjects in the Slovak Republic. Through pedagogical research, we found that pupils who used new textbooks to teach technical and science subjects achieved higher performance in the cognitive field of education than pupils who did not work with new textbooks. In our scientific research, we found that pupils in the experimental group also achieve higher performance at learning, comprehension, comprehension, and specific transfer. The differences in the performance of pupils in the control and experimental group of pupils in the levels of learning according to Niemi's taxonomy of education are statistically different. This scientific finding shows that a well-designed textbook for technical and science subjects allows pupils to remember and understand new knowledge and apply new knowledge in solving typical school and problem tasks. By applying a new textbook in technical and science education, we will achieve better and better results for pupils. We consider the process of creating textbooks for technical and science subjects to be very demanding. The effective combination of scientific knowledge and illustrations in the textbook contributes to pupils' effective acquisition of new information in the educational process. In the future, we plan to focus on verifying the textbook in the psychomotor field of education. By increasing the research sample and including pupils in the research sample from all regions of Slovakia, we can generalize the research results to all 5th-year pupils in the Slovak Republic.

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