Multidisciplinary approach based on the application of interdisciplinary connections in teaching natural sciences in lower secondary education stage

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Abstract: *This work describes a conducted pedagogical study aiming to find the benefit from the application of inter-and intradisciplinary connections in the field of information technologies-natural sciences during the training of students in lower secondary education stage. The role of the inter- and intradisciplinary connections in the education of natural sciences by the use of information technologies is discussed. The analysis of the results obtained from the applied training with the chosen methodology in 5th, 6th and 7th grade of a middle school is presented. The working hypothesis stating that the application of inter- and intradisciplinary connections in the corresponding field enhances the quality of the study process and the efficiency of the students' training in lower secondary education stage was confirmed.*

Keywords: natural sciences education, information technologies, inter- and intradisciplinary connections.

1. Introduction

The interdisciplinary connections in education play a key role in the multidirectional and overall development of students. They can be used as a tool for activating the students' cognitive ability. The establishment of the efficiency of such relationships in the training in natural sciences in lower secondary education stage and their interaction with the information technologies (IT) represent a challenge that needs a special attention. The conducted experimental training in natural sciences in 5th, 6th and 7th grade (general education preparation, interest activities), based on a methodology including interdisciplinary connections in the field of information technologies – natural sciences, aimed to find if the efficiency of students' education in lower secondary education stage could be enhanced in this direction.

The interdisciplinary connections can be realized by:

- integration of topics from different subjects in one lesson or project, where students can apply the acquired knowledge and skills in them.

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- organization of intersubjective modules, where students can study specific topics as they use their knowledge acquired from several subjects.
- creation of intersubjective projects or studies, where students can work in a team and apply their knowledge acquired from different subjects in order to solve real problems.

The use of such connections leads to a number of benefits for students:

- enhances their motivation (Stoitsov & Stoitsova, 2019) and engagement, as there is the possibility for them to participate in integrated and interesting projects which are significant and have practical applications;
- develops their social skills and work in a team, as students can work together and use their different skills and knowledge to solve tasks.
- more efficient application of knowledge and skills in real world, as students have the possibility to study topics from different sciences, which are connected to each other and have applications in real life.
- development of creativity and innovation skills, as students can use different knowledge and skills to create new ideas and solutions to problems.

1.1 Research aim and research questions

In the pedagogical dictionary, interdisciplinary connections are interpreted as the mutual coordination of educational programs, determined by the system of science and didactic goals. There are numerous publications related to the justification of this concept: (Velcheva, 2024), (Velcheva, Dimitrov & Shopova, 2023), (Mollov & Stoitsov, 2020), (Mollov, 2019), (Stoitsov & Stoitsova, 2019), (Chipangura & Aldridge, 2017), (Dori & Barak, 2001). The conclusion drawn from all of them is that interdisciplinary connections assist the creation of a more comprehensive and interdisciplinary educational program that reflects the real needs of students. This leads to greater student engagement in the learning process by allowing them to study topics related to their interests and with real-life applications.

The main aim of the current study is the approbation and processing of the results obtained from the applied multidisciplinary educational approach based on an interdisciplinary methodological model for teaching natural sciences in the 5^{th}, 6^{th} and 7^{th} grades of the lower secondary school which aims to increase the efficiency of educational activities through the use of interdisciplinary connections between IT and natural sciences.

The main question is whether the applied multidisciplinary educational approach could lead to an enhancement in the quality of the education process as well as in the efficiency of the students' training?

Hypothesis of the Study:

The education in natural sciences in 5th, 6th and 7th grades (extracurricular activities, interest-based classes), which is based on the use of interdisciplinary connections between information technologies and natural sciences, would lead to an improvement in the quality of the educational process and the efficiency of the education of students in the lower secondary education stage.

2. Research methodology

The pedagogical research was carried out during the 2019/2020, 2020/2021, and 2021/2022 school years according to the active regulation of Ministry of Education. This gives a reason to claim that the applied multidisciplinary approach and intstruments are modern in the conditions of the active regulations.

The inclusion of IT in educational programs leads to more modern, up-to-date and practical education that meets the needs and interests of contemporary students (Velcheva & Peykova, 2024), (Radev & Vazova, 2023), (Stoitsov & Stoitsova, 2019).

2.1 Sample

The following representative samples were selected for the study:

- 100 students from 5th grade divided in 2 groups consisted of 50 students – experimental (exp.) and reference (ref.) group;
- 100 students from 6th grade divided in 2 groups consisted of 50 students – experimental (exp.) and reference (ref.) group;
- 100 students from 7th grade divided in 2 groups consisted of 50 students – experimental (exp.) and reference (ref.).

A total of 300 students from the middle school in Plovdiv, Bulgaria, participate in the study. The check on the knowledge and skills was made by using tests, covering the study content:

- „Human and nature“ for students from 5th and 6th grade
- „Chemistry and environment protection” for students from 7th grade

2.2 Instrument and procedures

For the aims of the conducted experimental training with the interdisciplinary connections in the field of the information technologies, students used the following tools:

- Project “With a look to the stars” – graphics editors Paint 3D, GIMP and innovative educational applications for virtual and augmented reality Mozaik 3D (Shopova & Dimitrov, 2021), Smart Classroom AR, text

editor Google Docs.

- Project "Green zone", Project "Air pollution" – text editor Google Docs, editor of electronic tables Google Sheets, applications for content presentation Google Slides, Canva, Slidesgo (Shopova & Garov, 2022).
- Project "Healthy eating" - applications for content presentation Google Slides, PowerPoint, Canva, Slidesgo, text editor Google Docs.
- Project „Plovdiv Hills – the city symbol" – websites and educational applications Canva, LearningApps, Slidesgo, Wordwall, Word Mind, Popplet, virtual and augmented reality Mozaik 3D.
- Project "Structural formulas – a challenge for the 7th grader" – work with Internet and innovative software applications for VR and AR reality Google Arts & Culture, Mozaik 3D, Augment Education, applicable software ACD/ChemSketch.
- Project "Water – a source of life" - Canva, LearningApps, Slidesgo, Wordwall, Google tables, presentations and documents (Shopova, 2021).

The traditional structure of conducting the pedagogical experiment (three stages) was kept:

1. Preliminary experiments;
1.1. Determining the criteria and indicators for the assessment of the results from the tests;
1.2. Developing preliminary tests and tasks;
1.3. Developing a model for quantitative analysis of empirical data;
1.4. Selecting a representative sample and groups;
2. Intermediate control experiment
2.1. Training in the suggested methodology and study content;
2.2. Conducting a test and control exercises;
3. Final experiment
3.1. Analysis of test quality;
3.2. Analysis and presentation of the obtained results;
3.3. Formation of conclusions and assumptions.

The preliminary experiment aimed to provide an information for the preliminary level of the students on previously studied content (Bizhkov & Kraevski, 2002). During the training in the suggested methodology, an intermediate control was applied to check the results from the application of the suggested methodology. The final test was conducted in the end of the studied period.

The developed model (Shopova & Dimitrov, 2023) related to the implementation of interdisciplinary connections between natural sciences and

information technologies represents an organized and relatively stable configuration of the individual elements of the educational process:

- Idea for creating interdisciplinary connections;
- Design of teaching units;
- Development of educational content;
- Creation of teaching materials;
- Teaching in a new way;
- Organization of teaching time;
- Assessment and measurement of achievements;
- Analysis and results of the applied innovation.

3. Data analysis

The criteria and indicators for assessment of the results were selected according to the study program of the following subjects – "Human and nature" for students from 5th and 6th grade and "Chemistry and environment protection" for students from 7th grade. Such criteria and indicators were developed for the preliminary experiment as well as for the final tests for each grade. In this article, we will present only the criteria and indicators for the subject "Human and nature" in 5th grade.

3.1 „Human and nature" 5th grade, preliminary experiment

1. **Criterion 1** – Knowledge and skills, associated with bodies and matter

1.1. Compare matter, used in the casual life, according to their properties – the ability to burn, to be attracted by a magnet, to conduct heat, to be solved in water, to float or sink (heavier or lighter than water);

1.2. Give examples for the use of matter;

1.3. To list the pollutants of air, water and soil and the approaches for their protection;

2. **Criterion 2** – Knowledge and skills, associated with movement and energy

2.1. Illustrate with examples how the forces (muscular force, gravitation, friction) influence the movement and body shape;

2.2. To list the different types of energy, movement energy, heat energy, solar energy, fuel and food energy;

3. **Criterion 3** – Knowledge and skills, associated with the planet Earth

3.1. Link the change of the day with the night with the rotation of Earth around its axis;

3.2. Describe Sun as a star (source of light energy);

3.3. List the planets from the Solar system;

4. **Criterion 4** – Knowledge and skills, associated with vital processes

4.1. Describe the synthesis of nutrients in plants;

4.2. Explain the meaning of the plants for the air enrichment with oxygen and the removal of the carbon dioxide in air;

4.3. Explain from where the organisms receive energy and how they use it;

4.4. Give examples for animals breathing with lungs or gill;

5. **Criterion 5** – Knowledge and skills, associated with organisms and their living environment

5.1. Group the animals by their type – insects, fishes, amphibians, reptiles, birds and mammals;

5.2. Name the anthropogenic activities, leading to perturbation in the nature equilibrium as well as in the measures associated with its protection.

6. **Criterion 6** – Knowledge and skills, associated with human and his healthy way of life;

6.1. List the main nutrients that are necessary for the human organism and the foods that contain them;

6.2. Point the causes of contagious illnesses (microbes, bacteria, viruses) and tools for prevention and treating (personal hygiene, vaccines, medicines);

6.3. Explain the harmful influence of nicotine, alcohol and drugs.

3.2 „Human and nature“ 5th grade final test

1. **Criterion 1 -** Knowledge and skills, associated with bodies and matter

1.1. Give examples for diffusion and its meaning;

1.2. Measure the volume and mass of solids and liquids;

2. **Criterion 2** – Knowledge and skills, associated with heating

2.1. Describe the heating of solids;

3. **Criterion 3** – Knowledge and skills, associated with Earth and Outer space

3.1. Explain the change in the seasons, Moon’s phases, the lunar and solar eclipses with the movement of the Earth and Moon;

3.2. Compare the planets from the Earth’s group and gas giants according to specific features;

4. **Criterion 4** – Knowledge and skills, associated with matter and mixtures of matter.
4.1. Describe the matter by its content and physical properties;
4.2. Describe two- or multicomponent mixtures;
4.3. Properties of matter and mixtures of matter;
4.4. Application of matter and mixtures;
4.5. Differentiate matter and mixtures according to models;
5. **Criterion 5** – Knowledge and skills, associated with the air
5.1. Describe the air as a multicomponent mixture;
5.2. Point sources of atmosphere pollution – natural phenomena and anthropogenic activities;
5.3. Present different approaches for keeping the air freshness;
6. **Criterion 6** – Knowledge and skills, associated with water and aqueous solutions
6.1. Give examples for matter – water pollutants and their influence on the environment and human's health;
7. **Criterion 7** – Knowledge and skills, associated with the cell structure of organisms;
7.1. Define cell as a term;
7.2. List, point and index the cells and their parts (cell membrane, cytoplasm, DNA) on an image;
8. **Criterion 8** – Knowledge and skills, associated with vital processes in multicellular organisms;
8.1. Name the matter, necessary for feeding of plants and animals;
8.2. Determine the organs of the breathing system according to their function;
9. **Criterion 9** – Knowledge and skills, associated with the human vital processes;
9.1. List, point (on an image, model) and describe the organs and functions of the digestive system;
10. **Criterion 10** – Knowledge and skills, associated with human – a part of the nature;
10.1. Determine human as a part of the nature.

4. Research results

4.1 Preliminary level

The preliminary level of the students was assessed with preliminary tests in the corresponding subjects – "Human and nature" for the students from 5^{th} and 6^{th}

grade and "Chemistry and environment protection" for the students from 7th grade, included in the experimental study.

The histograms for each of the samples are presented on the following figures: 5th grade preliminary test.

The histograms on Figure. 1 are accompanied by the curve of normal distribution for each group with the corresponding parameters – mean and standard deviation. By using SPSS, a test of normality was done for the empirical results to determine the type of method used for a comparison – parametric or non-parametric.

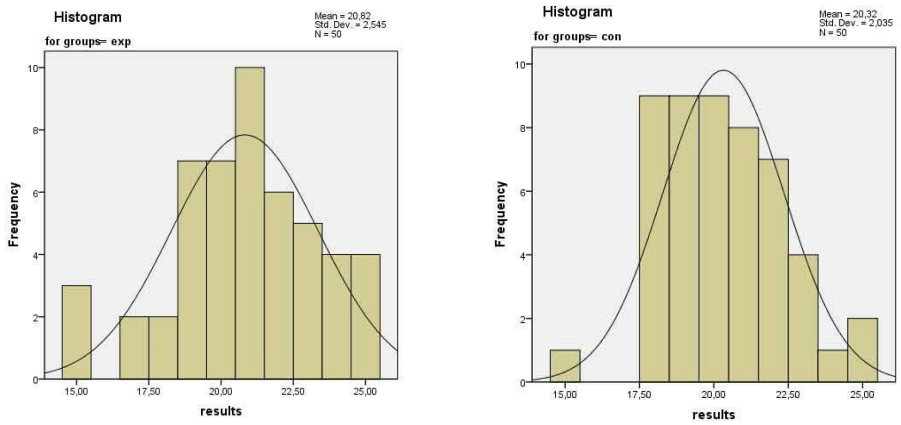

Figure 1. Histograms of the experimental and reference group for preliminary test 5th grade

The software presents the results in two variants shown in Table 1. The value of Sig. for the both tests (Kolmogorov-Smirnov, Shapiro-Wilk) of the two samples for 5th grade is above 0,05 which is a sufficient condition to conclude that the test results are normally distributed.

Table 1. Test for normal distribution

	groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
results	exp.	0,108	50	0,200	0,957	50	0,064
	ref.	0,122	50	0,059	0,957	50	0,068

In statistics, the normal distribution is of essential significance. It lays in the base of solving important cases in representative statistical studies, interval assessment, hypothesis confirmation and etc. The application of parametric tests for confirming hypotheses and studying the relationships between the variables requires preliminary study to find the degree to which the empirical data follows a normal distribution. In this case, the both samples are normally distributed and independent, therefore, T-test for independent samples was used for hypothesis confirmation. The null hypothesis is the assumption for equality of variances of the both samples.

The alternative hypothesis is that the variances are statistically different.

The aim was to determine from which of the both rows the value of Sig. (2-tailed) (Table 3) should be taken under consideration to make a conclusion for the statistical difference between the means.

Table 2. Group statistics

	groups	number	Mean	Standard deviation	Standard error of the mean
results	exp.	50	20,8200	2,54502	0,35992
	ref.	50	20,3200	2,03480	0,28776

Table 3. T-test for comparison of the means

		Leven test		T-test			
		F	Sig.	t	df	Sig. (2-tailed)	Difference between the means
results	**equal variances**	1,391	0,241	1,085	98	0,281	0,500
	different variances			1,085	93,473	0,281	0,500

The Leven test shows that the variances are not statistically different (Sig. 0,241>0,050), which determines that the value of Sig. (2-tailed) from the first row (equal variances) should be checked. The value is 0,281>0,050, which means that there is no statistical difference between the results from the preliminary tests of the both groups in 5th grade.

6th grade preliminary test

The Shapiro-Wilk test (Table 4) shows normal distribution for the both samples, which means that a parametric test for comparison should be used.

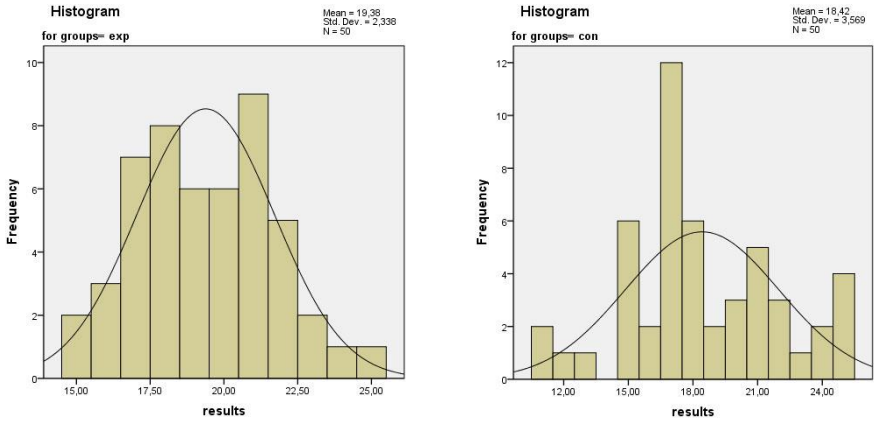

Figure 2. Histograms of the experimental and reference group for preliminary test 6th grade

Table 4. Test for normal distribution

	groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
results	exp.	0,123	50	0,058	0,972	50	0,284
	ref.	0,147	50	0,009	0,957	50	0,065

The applied T-test (Table 6) for two independent samples showed that there is no statistical difference between the results from the preliminary test for the two groups.

Table 5. Group statistics

	groups	number	Mean	Standard deviation	Standard error of the mean
results	exp.	50	19,3800	2,33771	0,33060
	ref.	50	18,4200	3,56908	0,50474

Table 6. T-test for comparison of the means

		Leven test		T-test			
		F	Sig.	t	df	Sig. (2-tailed)	Difference between the means
results	equal variances	6,961	0,010	1,591	98	0,115	0,960
	different variances			1,591	84,508	0,115	0,960

According to the Leven test, the variances are significantly different (heteroscedasticity of the samples) (Sig. 0,010<0,050) (Table 6), which means that the value of Sig. (2-tailed) from the second row (different variances) should be checked. The value is 0,115>0,050, therefore, there is a lack of statistical signify-cance between the results from the preliminary tests for the both groups in 6th grade.

7th grade preliminary test

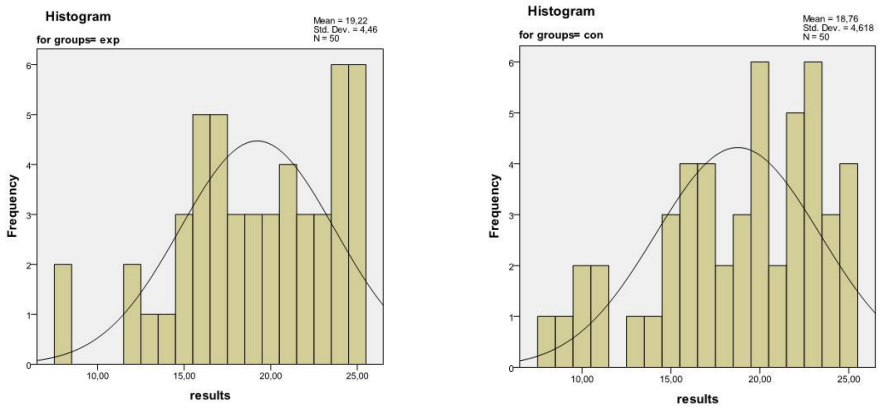

Figure 3. Histograms of the experimental and reference group for preliminary test 7th grade

The Shapiro-Wilk criterion (Table 7) shows that the both independent samples are not normally distributed (Sig.<0,050). Consequently, a non-parametric test for comparison should be used.

Table 7. Test for normal distribution

		Kolmogorov-Smirnov			Shapiro-Wilk		
	groups	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
results	**exp.**	0,102	50	0,200	0,938	50	0,011
	ref.	0,126	50	0,046	0,937	50	0,010

The applied Mann-Whitney test (Table 9) showed that the value for Asymp. Sig. (2-tailed) > 0,050, which means that there is no statistical difference between the results from the preliminary test for the both independent samples for 7th grade.

Table 8. Ranks

	groups	**number**	**Rank of Mean**	**Sum of ranks**
results	**exp.**	50	51,83	2591,50
	ref.	50	49,17	2458,50
	In total	100		

Table 9. Mann-Whitney test

	results
Mann-Whitney U	1183,500
Wilcoxon W	2458,500
Z	-0,460
Asymp. Sig. (2-tailed)	0,646

Summary of the results from the preliminary tests for the three grades

From the conducted statistical verifications of the preliminary level of the results of the experimental and reference group for the three grades, it can be concluded that the students start from the same level in the corresponding subjects.

4.2 Final tests

The final test was conducted for the corresponding samples after the training in the frames of the study year. The results from the final test aimed to confirm the working hypothesis that the use of the inter- and intradisciplinary connections information technologies - natural sciences enhances the quality of the study process and efficiency of the students' training in the lower secondary education stage.

5th grade final test

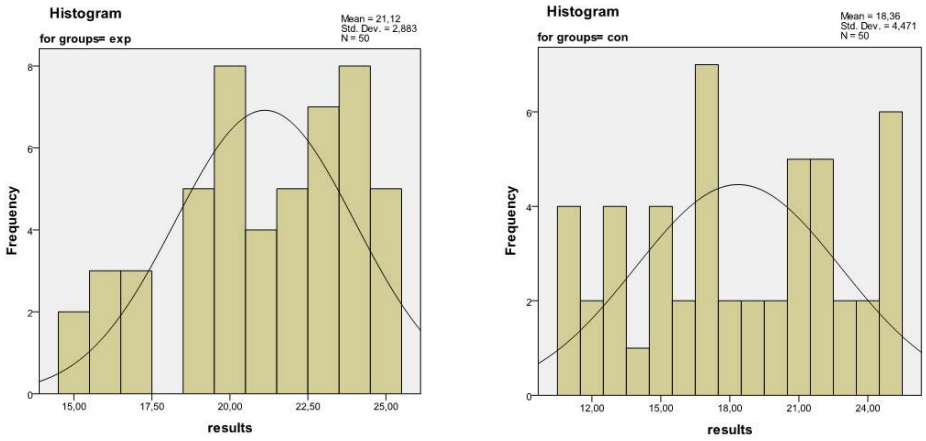

Figure 4. Histograms of the experimental and reference group for the final test in 5th grade

The mean of the experimental group is Mean=21,12 and the one of the reference group is Mean=18,36 (Figure 4). The difference between the means is 2,76 in benefit of the experimental group.

This result itself confirms the assumed hypothesis. However, a verification should be done to find if the difference between the means is a result due to improved methodology or randomness.

Shapiro-Wilk test (Table 10) showed that the results from the final test in 5th grade do not follow normal distribution (Sig.<0.05). In such case, the comparison between the two samples should be done by using a non-parametric test.

Table 10. Test for normal distribution

	groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
results	exp.	0,143	50	0,012	0,929	50	0,005
	ref.	0,123	50	0,058	0,939	50	0,013

In this case, the comparative analysis was done with the U-criterion of Mann-Whitney, which returned a result of 0,003 for Asymp.Sig.(2-tailed) (Table 12). Based on this result (significance degree <0,050), it can be concluded that the difference between the two measurements was not due to a randomness but rather it was a result from the applied methodology. With other words, the confirmation of our hypothesis does not have a random character.

Table 11. Ranks

	groups	number	Rank of the Mean	Sum of ranks
results	exp.	50	59,22	2961,00
	ref.	50	41,78	2089,00

	groups	number	Rank of the Mean	Sum of ranks
results	**exp.**	50	59,22	2961,00
	ref.	50	41,78	2089,00
	In total	100		

Table 12. Mann-Whitney test

	results
Mann-Whitney U	814,000
Wilcoxon W	2089,000
Z	-3,017
Asymp. Sig. (2-tailed)	0,003

6th grade final test

The mean of the experimental group is Mean=20,34 and that of the reference group is Mean=19,04 (Figure 5). The difference between the means is 1,30 in benefit of the experimental group. However, a verification should be done to find if the difference between the means is a result due to improved methodology or randomness.

Shapiro-Wilk test showed that the results for the experimental group from the final test in 6th grade are not normally distributed (Sig. < 0,050).

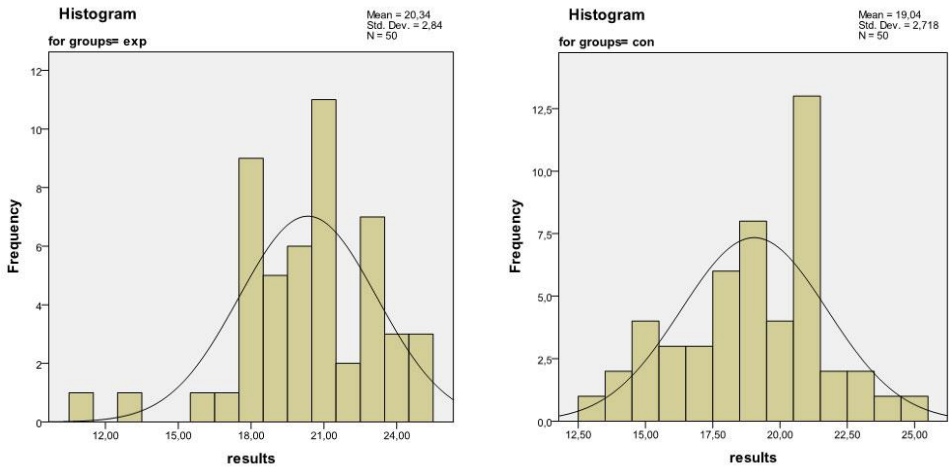

Figure 5. Histograms for the experimental and reference group for the final test in 6th grade

Table 13. Test for normal distribution

	groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
results	**exp.**	0,125	50	0,049	0,936	50	0,009
	ref.	0,145	50	0,011	0,964	50	0,134

Consequently, for the comparison of the both samples, the U-criterion of Mann-Whitney test was used which returned a result of 0,022 for Asymp.Sig.(2-tailed) (Table 15).

Table 14. Ranks

	groups	number	Rank of the Mean	Sum of the ranks
resuls	**exp.**	50	57,08	2854,00
	ref.	50	43,92	2196,00
	In total	100		

Table 15. Mann-Whitney test

	results
Mann-Whitney U	921,000
Wilcoxon W	2196,000
Z	-2,293
Asymp. Sig. (2-tailed)	0,022

Based on this result (significance degree <0,050), it can be concluded that the difference between the two measurements is not due to a randomness but rather it is a result from the applied methodology. With other words, the confirmation of our hypothesis does not have a random character.

7th grade final test

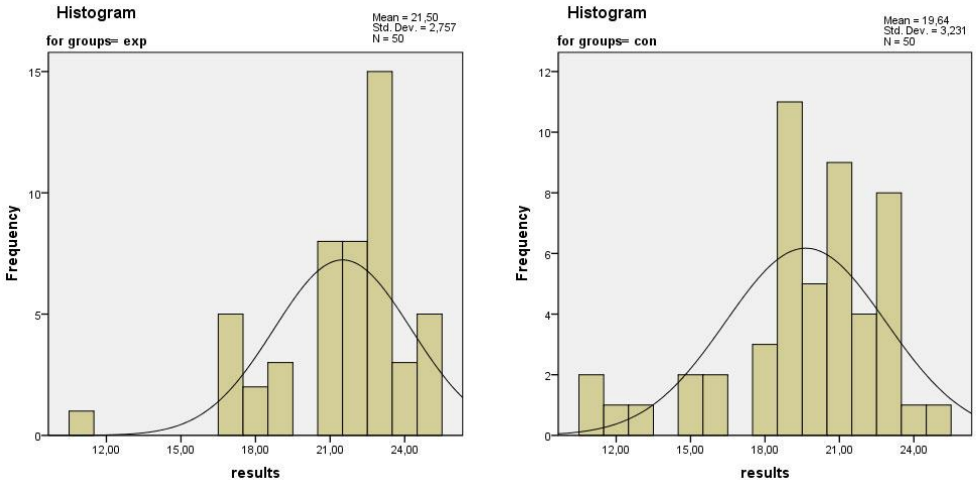

Figure 6. Histograms for the experimental and reference group for the final test in 7th grade

The mean of the experimental group is Mean=21,50 and that of the reference group is Mean=19,64. The difference between the means is 1,86 in benefit of the experimental group. However, a verification should be done to find if the difference between the means is a result due to improved methodology or randomness.

The value of Sig. for the two tests (Kolmogorov-Smirnov, Shapiro-Wilk) of the both samples for 7th grade final test is below 0,05, which is a sufficient condition to conclude that the test results do not follow normal distribution.

Table 16. Test for normal distribution

		Kolmogorov-Smirnov			Shapiro-Wilk		
	groups	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
results	**exp.**	0,208	50	0,000	0,860	50	0,000
	ref.	0,201	50	0,000	0,900	50	0,000

From the made conclusions for the both groups, it follows that a non-parametric method should be used for comparing the results of the both independent samples. For this aim, the comparative analysis was done with the U-criterion of Mann-Whitney which returned a result of 0,001 for Asymp.Sig.(2-tailed) (Table 18).

Table 17. Ranks

	groups	**number**	**Rank of the Mean**	**Sum of the ranks**
results	**exp.**	50	59,87	2993,50
	ref.	50	41,13	2056,50
	In total	100		

Table 18. Mann-Whitney test

	results
Mann-Whitney U	781,500
Wilcoxon W	2056,500
Z	-3,266
Asymp. Sig. (2-tailed)	0,001

Based on this result (significance degree <0,05), it can be concluded that the difference between the two measurements was not due to a randomness but rather it is a result from the applied methodology. With other words, the confirmation of our hypothesis does not have a random character.

5. Discussion

From the made statistical verifications for the final level of the results of the experimental and reference group for the three grades, it can be concluded that the difference in the levels of the results in the individual measurements for the corresponding levels is not due to randomness but rather it is a result from the applied methodology. Thus, the working hypothesis stating that the use of the inter- and intradisciplinary connections information technologies - natural sciences enhances the quality of the study process and efficiency of the students' training in lower secondary education stage was confirmed.

6. Conclusions

The aim of the current work was to present the results from the training of students from the lower secondary education stage (5^{th}, 6^{th} and 7^{th}) by using a methodology, including interdisciplinary connections in the field of IT and natural sciences. Various software products and technologies were used that assisted the teaching in natural sciences during the general education preparation and interest activities through the performance of projects. The analysis of the obtained results from the teaching by using this methodology showed better students' assimilation of the study content.

The obtained objective information from the processing of the results from the conducted pedagogical study is only one example for confirming the assumption that the use of innovative approaches in the training has a beneficial influence on the quality of the training and on the improvement of the process of perception of the given study content.

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