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Inquiry as a Part of Educational Reality in Technical Education

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Abstract

In the proposed study, the authors focus on the situation in the field of technical education in Slovak primary schools and present the results of an original research study focused on the application of an inquiry-based approach. The main goal of the investigation was to compare the efficiency of using inquiry-based activities in teaching selected topics (Electromagnetism and Electronics) with the efficiency of traditional teaching methods where students follow their teacher's instructions. In the presented research study, carried out in four primary schools, the methods of pedagogical experiment and didactic tests examining students' knowledge on the three levels of Niemierko's taxonomy were used. The authors of the study present their findings regarding the impact of inquiry-based teaching on 6th grade students' knowledge, activity, and motivation. Based on the obtained results, it can be assumed that inquiry-based teaching can lead to better knowledge acquisition, increased student activity, and a higher motivation to learn compared with applying traditional methods of teaching. The results of the t-test confirmed the significance of differences between the experimental group's and the control group's performance in all three observed fields. The authors believe that the presented findings can contribute to improving the quality of the educational process not only in technical education but in other fields of didactics as well.

Keywords:

Inquiry-Based teaching; Education; Learning; Educational Reality; Technical Education.

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1- Introduction

At the end of the 20th century, technical education went through a deep crisis. It can be assumed that the crisis had several causes. The first was represented by social changes related to the transition from a technical and technological society to an information and learning society. Information and communication technologies were developing fast and working with information, their searching, sorting, and critical evaluation became a necessity. The earlier applied transmissive approach to technical education focusing on developing craft skills had shown to be unsatisfactory.

The second reason for searching a new paradigm in technical education was students' disinterest in science and technical education. Such disinterest can be observed practically at all levels of education even today, and it is also reflected in the number of applicants interested in studying at technically or science oriented vocational schools and universities [1]. The occurring disinterest in natural and technical sciences is – from the aspect of the needs of a modern society – so critical that decisive and commercial spheres have introduced educational programmes actively promoting science and technical study programmes. At the end of the 20^{th} century, several developed countries realized the need to change the existing systems of education, as traditional schools did not sufficiently prepare their students for living in modern society.

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The EU Lisbon Summit of March 2000 launched the clear goal to make Europe "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion" by 2010 [2]. The European Commission [3] – in the report "Europe needs more scientists" – clearly declared the need for high quality education and subsequently, in 2007, the document "Science education Now!: A Renewed Pedagogy for the Future of Europe" [4] emphasizing that changes in education can be achieved by implementing the methods of active inquiry was released. These and other reasons have led to school reforms in the European Union, including Slovakia. The significance of the associations between countries' economic growth and the population's skills is accentuated by OECD economists Hanushek and Woesmann [5]. They claim that in the context of countries' economic growth, skills related to thinking and learning, such as critical thinking or problem solving, have a key role to play. They claim that these factors are much more important from the aspect of countries' economic growth than school attendance, which is overemphasized, and insufficient attention is paid to school quality and the skills that are developed in them.

The level of skill development in relation to critical thinking and learning is measured by international comparative assessment tests, such as PISA, TIMMS, etc. Hanushek and Woesmann [5] claim that countries achieving good results in PISA exams are likely to have higher GDP growth. Competencies for scientific work, including hypothesis formulation, proposing solution methods, formulating conclusions, and argumentation, provide a platform for developing 21st century skills. The question remains that which are the teaching concepts by which the requirements in the field of developing competencies for scientific work can be met. Teaching concepts based on active inquiry – i.e., inquiry-based teaching – can be considered an option.

The presented study is a reaction to the most up-to-date international tendencies in education reflected in the application of inquiry-based teaching at all levels of education. The purpose of the implementation of these methods of teaching – among other things – is to develop students' problem-solving competencies. These competencies are not perceived as tied to individual subjects but are considered multidisciplinary competencies applied to particular activities. The importance of developing problem-solving skills in students is emphasized in the work of several authors, e.g., Lesh and Zawojewsky [6], who claim that a developed problem-solving ability facilitates further education, successful involvement in society, and is necessary for a range of personal activities as well. As confirmed by other authors [7-10], inquiry-based teaching has shown to be a promising method of education.

The popularity of inquiry-based teaching stems from the fact that earlier reform efforts mostly ended unsuccessfully. They lacked systemicity, did not include the field of undergraduate teacher training, and therefore, following a short period of popularity, their impact was gradually weakening.

The concept of inquiry-based teaching is a reaction to criticism focusing on the basic deficiencies in science and technical education. Held [1] calls this concept "school science". Unlike transmissive procedures – within which information is presented to students as definitive, infallible, and clearly proven – for the inquiry-based approach, experimental verification of existing presumptions and theories, their questioning, and proposing new concepts are characteristic. Inquiry-based teaching is very close to the work of researchers. It is a concept of searching for alternatives, trials and errors, and it does not lead to achieving goals straightforwardly. Students learn to apply a critical approach to the presented information and work with errors and mistakes. The basic unit of knowledge is not represented by facts but by methods, procedures, and processes. The purpose is to develop a general ability to find, discover, and learn the principles of scientific research [11].

This new paradigm of education aims to provide students with a more open, accessible, and liberal education that focuses on their individuality and personality development to a greater extent, where a shift from knowledge to competencies, from teaching to learning, can be observed, and where students are at the center of attention. During inquiry-based education, students collaborate. They are usually divided into groups based on their interests and abilities. Teachers lead students towards revealing mistakes and inaccuracies, but also self-evaluation, which facilitates their further development. The emphasis is placed on inquiry, understanding relationships, and not memorizing facts. That is what distinguishes inquiry-based teaching from traditional, reproductive teaching. Inquiry-based teaching means a shift from a system based on learning facts to a system of teaching accentuating conceptual understanding and a logical process of developing knowledge and skills.

It comes with a change in the role of teachers as well. Teachers become facilitators, designers, and managers of their students' learning processes. They develop methods, materials, and situations that promote students' active learning, provide consultations, give advice, and coordinate activities.

In the process of inquiry, several levels of students' independence can be identified. In the presented research study, the definition by Banchi and Bell [12] was worked with, and the applied levels were suggested based on the intensity of the teachers' help and participation in the experiment (Table 1).

Level of inquiry	Questions suggested by the teacher	Procedures suggested by the teacher	Solutions suggested by the teacher
1. Confirmation Inquiry	yes	yes	yes
2. Structured Inquiry	yes	yes	no
3. Guided Inquiry	yes	no	no
4. Open Inquiry	no	no	no

Table 1. Levels of inquiry [12]

The issues of the level of students' and teachers' involvement in the process of inquiry were dealt with by e.g. Spronken-Smith et al. [13], Zion and Mendelovici [14], and Orosz et al. [8]. The first level is represented by confirmation inquiry, where the problem, experimental procedures, and the solution are suggested by the teacher, which means that the students' only task is to reproduce the inquiry as they know what the expected result is. In the case of structured inquiry, the procedures are projected by the teacher, but the solution is suggested by the students based on the results of their measurements and observations. This type of activity provides limited opportunities for independent thinking and students follow a given pathway to the solution. In spite of these shortcomings, it can be a useful method for practicing relatively simple inquiry skills (e.g. observation, measurements, data interpretation, discussing results, introduction to inquiry-based learning). The next level is represented by guided inquiry, where the problem is still suggested by the students. The activities of guided inquiry offer opportunities for cooperative learning and provide more space for students' creativity and developing their skills and abilities. The highest level of inquiry-based teaching is open inquiry, where the teacher's tasks is limited to specifying the theme and the students' learning objectives. The students select a problem and research hypotheses they want to examine. Such activities provide the highest level of freedom and require advanced research skills (critical thinking and creativity), but also bring the highest degree of responsibility.

Several authors (e.g. Fay et al. [15]) – to avoid terminological issues – simply assign numbers to individual levels of inquiry. The highest the number is, the highest degree of freedom students have during the inquiry. Students' higher autonomy can be a motivating factor for students, but it is important to be cautious about not overloading students with information [16].

2- Purpose of the Study

Although there are undoubted potentials for inquiry-based teaching, in general, for various reasons, students do not have sufficient opportunities to carry out experiments or other inquiry-based activities. In the inquiry-based approach, a crucial role is played by teachers, whose ways and principles of teaching have an impact on students. As research findings show [8, 17-19], teachers lack competencies in the field of implementing inquiry-based activities, and international knowledge and experiences point to the fact that teachers' professional preparedness has a significant impact on the quality of education. Teachers must be well prepared for any changes to be introduced, and therefore, in the case of those who did not receive sufficient undergraduate training in the field, in-service teacher training opportunities focused on innovative strategies and methods, as well as their implementation, should be created. Also, teachers should receive learning and teaching materials, which would help them gain confidence in carrying out inquiry-based activities. Teachers also often complain about not having access to verified inquiry-based procedures, which can be easily applied in the classroom [8]. Although currently used textbooks and teaching materials contain several examples of problem-solving tasks and experiments, teachers consider them insufficient. They complain about not being provided with any instructions on how to use the activities in the classroom, although teachers' abilities to ask appropriate questions and to manage students' inquiry-based learning are decisive in terms of the success or failure of their realization.

The presented study deals with the issues of technically oriented inquiry-based activities based on guided inquiry, which were examined on the sample of 6th grade students. Students were familiar with the basic methods of scientific research as they had learned about them in Technics classes prior to the realization of the research, but they lacked practical experiences. The conducted research was focused on the implementation of experiments in the framework of inquiry-based teaching in the form of newly developed modules, which were reviewed by experts and teachers. Each teaching module was associated with the optimal model (strategy) of inquiry-based teaching. The teaching modules were evaluated as appropriate means of motivating students and promoting their independent and active work. The main goal of the study was to find out about the extent of students' active learning. We aimed to find out whether the developed teaching modules including experiments increase the extent of students' active learning during Technics classes in lower secondary schools. We also examined, whether using the developed teaching modules. To meet the research goals, the methods of natural experiment and didactic tests were used. The process of teaching was observed, which allowed us to learn about the students' educational pathways and to gather information about their individual steps. Based on these observations, we identified when the students needed more help and guidance and what caused the students problems in order to provide teachers with recommendations.

The second goal was to investigate the participating students' feelings during the activities. We were interested in the perceived quality of communication in the classroom, feeling of freedom, whether they experienced success, pleasure from solving the assigned tasks, and received appraisal from their teacher or peers, which we denoted as cognition in the study. In this part, students usually evaluate their performance, too. The students' attitudes towards the activity and self-evaluation were examined by means of the standardized AUS questionnaire by Rötling and Sihelsky [20] and other author-constructed attitude questionnaires. Given by the nature of our research, application of several research methods and techniques was necessary. By means of them, we revealed several specifics and gathered contextually rich data.

During the three-year research project, new teaching materials (teaching modules) promoting inquiry-based teaching in technical education in Slovakia were designed.

3- Research Oriented on Inquiry-Based Teaching in Technical Education

3-1-Research Goals and Objectives

The main goal of the research study was to verify inquiry-based activities consisting of 12 modules developed in compliance with the curriculum for technical subjects. The main goal of the research was related to the following research questions:

- Will students in the experimental group educated by means of inquiry-based activities achieve better results than students in the control group educated by means of conventional methods?
- What impact do research-based activities have on students' motivation, knowledge, and activity in the experimental group?

Our task was to compare the efficiency of inquiry-based teaching (experimental group) with the efficiency of traditional teaching (control group).

For finding answers to the above research questions, DBR (Design-Based-Research) was applied. The concept of DBR is not revolutionarily new. In available literature, this research design is also referenced to as design experiment, formative research, etc. [21]. According to Hutterer [22], each pedagogical research working with an experimental plan must include intervention in the experimental group, which means that researchers implement innovation on the sample of students or teachers in real classrooms. In this phase, the researcher is developing rich knowledge about the necessary conditions for and limits of innovations' functioning or collects information about research subjects' experiences (e.g. teachers in experimental classrooms). This knowledge should make communication with teachers easier while implementing theory into practice.

One of the important aspects of the carried out research activities was the attempt to build relationships between the researcher and the respondents based on mutual trust. The principles of ethics were applied throughout the whole research process, which helped prevent the occurrence of obstacles in data collection. The applied design-based research organically integrates research and developmental objectives, which are inseparable and interdependent. Alongside with that, it is organically connected with practice in the form of cooperation with primary school teachers and students.

For meeting the main goal, the following research hypotheses were formulated:

- *H1:* The students in the experimental group will achieve statistically significantly higher scores in didactic tests than the students in the control group.
- *H2:* The students in the experimental group, where inquiry-based modules are applied, will be statistically significantly more active on lessons than the students in the control group.
- *H3:* The students in the experimental group, where inquiry-based modules are applied, will be statistically significantly more motivated than the students in the control group.

3-2-Methods and Research Tools

The realized quantitative research required the application of several research methods and techniques. In the hypothesis-verification process, the below research methods and techniques were applied. For examining students' knowledge on the three levels of Nemierko's taxonomy [23], author-constructed didactic tests were used. The quality of the administered questionnaire was earlier examined by Dostál and Kožuchová [24], who used it for a similar purpose in the context of the educational work in Czech primary schools. A satisfactory level of psychometric properties (reliability and validity) of the research tool was confirmed. In the process of developing the main research tool, following the approval by the authors of the original questionnaire, a modified combination of six selected items (statements) extracted from the original questionnaire was used.

The standardized AUS questionnaire (Aktívne Učenie Sa – Active Learning) measuring students' active learning [25] and the standardized MPU (Motivačné Pôsobenie Učiteľa – Teacher's Motivational Impact) for measuring teachers'

motivational impact on students [26] were used. The above design allowed us to develop a rich knowledge regarding the necessary conditions and limits related to innovations' functioning. During the research, the developing specific relationships between the researchers and the research participants (students and teachers) could not be overlooked.

To find out about the effect of inquiry-based activities, a pre-tests and a post-test were designed. The pre-test was administered to students prior to the realization of research activities. Further tests were taken by students approximately every fourteen days until the end of experimental teaching in order to find out whether the effect is long-term. The same tests were administered in the control group. Both the pre-test and the post-test consisted of 16 items, which were either identical or similar and were always focused on the field associated with the carried-out activities. The maximum score was 40.

3-3-Research Sample

The research study was carried out in four primary schools in Slovakia providing also lower secondary education (three primary schools in Banská Bystrica and one primary school in Prievidza) in eight parallel groups of 6th grade students. As in the case of the school subject Technics, regulations allow dividing classes of students into two groups, each of the observed classes had worked in two groups since the beginning of the school year. Students were divided into two groups according to alphabetical order. Sorting students according to their surnames can be considered random distribution. It was the reason for processing data as a selection from the normal distribution. From the aspect of the external validity, stratified sampling was applied. In total, 150 students (67 male students and 83 female students) took part in testing the proposed activities (Table 2). For an objective evaluation of whether the proposed activities have an impact on the level of students' active learning within the subject Technics, both experimental and control groups were involved in the research study in each class.

School	Number of participants
1. School A _{EXP1}	20
2. School B _{EXP2}	24
3. School C _{EXP3}	20
4. School D _{EXP4}	11
5. School A _{CON1}	21
6. School B _{CON2}	21
7. School C _{CON3}	20
8. School D _{CON4}	13
	150

Table 2. Number of students involved in the research study

EXP – Experimental Group; CON – Control Group.

The participating students were aged between 11 and 12 years. In the experimental groups, inquiry-based activities were applied. First, the inquiry-based tasks in modules were introduced to students and, in groups of four, they were supposed to propose possible ways of solving tasks, including a school experiment. Their task was to carry out the experiment, to evaluate its results, to discuss various issues within and between groups, and to compare their results. Finally, they formulated conclusions. The control group worked on the same topics, but a traditional approach was applied with them, and they followed their teachers' instructions including particular steps to be carried out. Within the research, 12 modules focusing on two thematic fields – Electromagnetism and Electronics – were developed. Experimental teaching was carried out during the period of three months (February – April 2022). In order to prevent the influence of teachers' approach on the research results, both groups were taught in compliance with the above-described conditions.

3-4-Realization of Research

In the first phase of the research study, two phenomena were in the centre of the research team's attention that were considered priorities – the first was examining students' cognitive performance (knowledge) by means of authorconstructed entrance and final didactic tests (pre-test and post-test) as it was presumed that students in the experimental group wouldacquire more knowledge during active work than students in the control group. The second phenomenon was students' motivation associated with individual activities and their cooperation with their teacher. To measure the teachers' motivational impact, the standardized MPU questionnaire (Teacher's Motivational Impact) by Rötling et al. [26] was used. We presumed a statistically significantly stronger impact of teachers' motivational work in the experimental group. The rate of the students' active learning was measured by means of the standardized AUS – Aktívne Učenie Sa (Active Learning) questionnaire (Figure 1).



Figure 1. Methods and materials for the three phases of the research study

4- Research Results

4-1-Examining Students' Performance in the Cognitive Field

In the first phase, the research study was focused on examining the input-output results of students. The input-output performance measuring showed the students' progress achieved in selected thematic units in the subject Technics. The statistical models were based on students' performance in the didactic pre-test and post-test at the beginning and at the end of the testing period.

In Figure 2, descriptive statistics for both selection groups is presented. The control group (considering the position of the interquartile range, the minimum, and the median) achieved lower scores than the experimental group. If in both the experimental and the control groups the conditions for teaching relevant from the aspect of the final didactic test (post-test) – by which the participating students' knowledge on the first three levels of Niemierko's taxonomy (remembering, understanding, and specific transfer) was examined – were comparable, then – with a 95% probability – the arithmetic mean of the control group would be in the confidence interval (113.369; 115.150). As the data come from normal distribution, it can be assumed with a probability of 95% that there was a significant factor influencing the arithmetic mean in both groups.



Figure 2. Hypothesis 1 – Didactic test (boxplot)

The results of the t-test confirmed the existence of statistically significant differences between the performance of the experimental group and the performance of the control group, which were caused by using inquiry-based activities in the framework of the experiment. The observed differences point to the fact that inquiry-based activities have an impact on students' overall performance in the cognitive field, which was measured by administering the didactic test (Table 3).

	Levene Equality ('s Test for of Variances	t-Test for Equality of Means						
	F	P – value F test	Т	df	P - value two-sided alternative	Difference of mean values	Mean value error	95% coi interval fo	nfidence r variance
Equality of variance	32.662	0.000	24.39	75	148	15.7066	0.64378	-1.72731	0.03272
Inequality of variance	0	0	24.39	205.41	105.44	15.7066	0.64378	-1.72745	0.03285

Table 3. Two-sample t-test for hypothesis H1

By means of a t-test, it was confirmed that the difference in the arithmetic means of the summary score in the didactic test was statistically significant on the significance level $\alpha = 0.05$. For the purposes of the final analysis, it was necessary to examine the homogeneity of variance. It was calculated using Barlett's and Cochran's tests for homogeneity. The results are displayed in Table 4.

	Cochran T.	Hartley T.	Bartlett T.	Р	Degrees of freedom
Score	0.69874	1.367117	0.026354	0.948322	1

Table 4. Test of variance homogeneity

The research results confirmed the first hypothesis (H1), in which it was presumed that the students in the experimental group would achieve significantly higher scores in didactic tests than the students in the control group. The hypothesis H1 was confirmed.

4-2- Examining Students' Rate of Active Learning

The rate of students' active learning was examined by means of the standardized AUS – Aktívne Učenie Sa (Active Learning) questionnaire. The obtained data were analysed using descriptive statistics.

The findings show that students in both groups reflected on the extent of active learning differently (Figure 3). A higher rate of active learning was observed in the experimental group where the students actively constructed their knowledge through inquiry-based activities. Students had more favourable conditions for their activities, which is supported by the median of the measured scores.



Figure 3. Hypothesis 2 – AUS questionnaire (boxplot)

The performed t-test confirmed significant differences between the performance of the experimental group and the performance of the control group, which was affected by using inquiry-based activities within the experiment. The measured differences pointed to the fact that inquiry-based activities have an impact on students' active learning. The calculated values confirmed the hypothesis regarding the significance of the differences between the arithmetic means of the score for the dependent variable "ACTIVITY" (Table 5).

	Levene Equality	's Test for of Variances	t-Test for Equality of Means						
	F	P – value F test	Т	df	P - value two-sided alternative	Difference of mean values	Mean value error	95% coi interval fo	nfidence r variance
Equality of variance	23.278	0.000	15.850	148	0.000	5.600	0.35330	3.6130	4.9018
Inequality of variance	0	0	15.850	123.73	0.000	5.600	0.35330	3.6128	4.9007

Table 5. Two-sample t-test for hypothesis H2

The performed t-test confirmed that the difference in the averages of total the scores for the standardized AUS questionnaire in the case of the independent variable "ACTIVITY" was statistically significant on the significance level $\alpha = 0.05$. For verifying the hypothesis, parametric tests were used (Table 6).

Table 6.	Test of	variance	homogene	eity
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	Cochran T.	Hartley T.	Bartlett T.	Р	Degrees of freedom
ACTIVITY	0.56985	1.167100	0.05350	0.847333	1

The research results confirmed the presumptions formulated in hypothesis H2. In the experimental group, with which the modules were applied, students were more active compared with students in the control group, with which traditional methods of teaching were used. The hypothesis H2 was confirmed.

4-3-Examining the Rate of Teachers' Motivational Impact

The rate of teachers' motivational impact on students was examined by means of the standardized MPU – Motivačné Pôsobenie Učiteľa (Teacher's Motivational Impact) questionnaire. As an additional method of research, non-standardized in-depth interviews were carried out. The students were asked to assess their teacher's motivational impact in five fields: communication, freedom, success, appraisal, and cognition.

The value of the arithmetic mean (17.075) for the experimental group corresponds with the category, where the teachers' motivational impact is very good. The value of the arithmetic mean in the control group (12.065) suggests that according to the students, the teacher's motivational impact was not satisfactory – i.e. it was weak. The difference between the median in the experimental group and the median in the control group is more than 5 points, which – in the case of using the MPU questionnaire – means a difference of more than one class.

In the case of the variable "MOTIVATION" – as displayed in Figures 4 to 9 – based on the results in all observed fields (communication, freedom, success, appraisal, and cognition) and the calculated total sum of the measured values, it can be assumed that in the experimental group, high levels of the teacher's motivational impact on students were found. The motivational impact of the teacher in the control group was perceived significantly less positively.



Figure 4. Hypothesis 3 – Communication (boxplot)



Figure 8. Hypothesis 3 – Success (boxplot)



Figure 9. Hypothesis 3 – Sum (boxplot)

In relation to the variable "MOTIVATION", based on the performed t-test, respectively on the total sum, we can assume that our presumption regarding the existence of a significant difference in the field of motivational impact was confirmed. The measured values point to the fact that inquiry-based activities had an impact on the students' motivation in all the observed fields (communication, freedom, success, appraisal, and cognition), respectively on the sum of the measured values and so, the presumption of a different intensity of the teacher's motivational impact on students in the experimental and control groups was confirmed. The hypothesis H3 was confirmed (Tables 7 and 8).

Table 7.	T-test for	MOTIVATION	(Freedom,	Success, A	ppraisal, (Communication,	Cognition)
			(~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~			

	Freedom	Success	Appraisal	Communication	Cognition	Total MOT
Arithmetic mean (experimental)	17.31	17.53	17.96	17.96	15.65	16.49
Arithmetic mean (control)	10.13	10.22	11.21	11.12	13.44	11.58
Calculated t-value	18.2354	8.55777	12.56984	10.15466	7.25698	21.33568
Degrees of freedom				60		
Significance	sig.	sig.	sig.	sig.	sig.	sig.
Р	P<<0.001	P<<0.001	P<<0.001	P<<0.001	P<<0.001	P<<0.001
		Auxiliary o	alculations			
Valid values (experimental)				48		
Valid values (control)				46		
Standard deviation (experimental)) 1.5469366	1.569867	1.2365474	1.632548	1.123546	0.869532
Standard deviation (control)	1.5021365	2.451278	1.6541236	1.451136	2.124569	1.124500
F - variance ratio	1.4521363	2.455123	1.4785469	1.123654	1.457896	1.412569
Р	0.7456986	0.002356	0.4125699	0.147852	0.456987	0.145698
	f-crit(0.05;42)=	it(0.05;42)= 1.72223 t-cr		5;60)= 1.55804		

MOT – MOTIVATION

Fable 8. Variance analysis - MO	TIVATION (Freedom, Success,	Appraisal, Communication,	Cognition)
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	Systematic variance Module	Systematic variance Student	Random variance	Total variance
Degrees of freedom	1	94	94	62
Freedom	704.06	68.68	56.25	841.24
Freedom F value	260.431	1.275		
Freedom p value	P<<0.001	0.21838	Impact of the modu "Freedom"	ale on the variable
Results - Freedom	Significant	Not significant		
Success	314.01	219.03		
Success F value	137.669	2.541	Impact of the module on the variable	
Success p value	p<<0.001	0.006180	"Success"	' 53.45%
Results - Success	Significant	Significant		
Appraisal	500.00	136.00		
Appraisal F value	177.457	1.612	Impact of the modu	ale on the variable
Appraisal p value	p<<0.001	0.062871	"Appraisal	" 73.55%
Results - Appraisal	Significant	Not significant		

Communication	437.45	224.37	Impact of the module on the variable "Communication" 69.84%
Communication F value	432.53	3.77	
Communication p value	p<<0.001	0.0021614	
Results - Communication	Significant	Significant	
Cognition	252.01	146.25	Impact of the module on the variable "Cognition" 52.32%
Cognition F value	98.236	1.364	
Cognition p value	p<<0.001	0.12458	
Results Cognition	Significant	Not significant	
Motivational impact	502.02	66.80	Teaching module's motivational impact coefficient; 76.47%
F value	10378.8	57.0	
p value	p<<0.001	P<<0.001	
Results – Motivational impact	Significant	Significant	

The research results confirmed our presumptions formulated in hypothesis 3, which is that in the experimental group, with which the inquiry-based modules were applied, students motivation was significantly higher compared with students in the control group, with which traditional methods of teaching were applied by the teacher. The H3 was confirmed. Its validity can be generalized on the research sample.

5- Discussion

The main goal of the research study was to find out whether applying certain elements of inquiry-based teaching can lead to better knowledge acquisition, to an increase in students' activity, and a higher motivation to learn than traditional methods of teaching characterized by following teachers' instructions. Based on the obtained results, it can be assumed that the applied type of teaching has a significant impact on students' knowledge. It can be explained by the fact that from time to time, prior to the realization of inquiry-based activities, students were asked to study materials about the particular topic to be discussed in advance.

Only a few authors have found a positive impact of inquiry-based activities in the field of knowledge acquisition. Such results were obtained by some authors of older publications [27], but also by authors of more recent studies [28, 29]. They found out that applying the elements of inquiry-based teaching has a statistically significantly positive impact on knowledge acquisition. Similar results were found by Nezvalová [30] in the Czech Republic and a positive effect was also revealed in the research study by Ryplová and Reháková [31]. On the other hand, according Cobern et al. [32] – in the field of knowledge acquisition and the amount of newly gained knowledge - the results of inquiry-based teaching and traditional teaching methods are comparable, and according to Jerrim et al. [33], there is a little evidence about the existence of a positive association between the frequency of inquiry-based instruction and students' performance in science examinations. The effectiveness of inquiry-based teaching in the field of knowledge acquisition was disputed by e.g. Hodson [34], Zhang [35], Kirschner et al. [36], and Rosenshine [37], according to whom it can be considered a limiting factor. Hmelo-Silver et al. [38] in the reaction to the work by Kirschner et al. [36] argue that especially guided inquiry-based teaching is effective, which is in line with our findings. Rokos [39] highlights that inquiry-based teaching does not ensure a significant improvement in students' knowledge, but it allows them to master methodic procedures, which can help them independently solve new problems in the future, which is the opposite to what Gibb [40] claims. According to him, giving students too much freedom in designing, carrying out, and discussing the results of experiments in the UK "resulted in a net negative impact on science outcomes".

Several authors have dealt with the impact of inquiry-based teaching on skill development and accentuate that it helps achieve better results than traditional teaching. Dostál and Kožuchová [24] claim that inquiry-based teaching promotes developing skills related to inquiry, which is in line with our finding that statistically significantly better results were achieved by the students in the experimental group in the field of research skills (measuring, communication, classification, interpretation, and making assumptions) compared with the control group where traditional procedures were used. Based on their research results, also Rokos and Vomáčková [41] claim that the applied type of teaching has a significant impact on students' skills. In the case of the students in our experimental group, their research skills were developed to a greater extent than in the students taking part in traditional education.

Since there are no available Slovak or Czech studies in which the impact of inquiry-based activities on students' motivation was proven, in the presented research study, we focused on these two phenomena. The observed differences point to the fact that inquiry-based activities have an impact on both students' activity and their motivation in all the observed components.

The process of motivating and activating students did not take place exclusively during lessons, but also prior to the realization of activities, when teachers used well-known motivating factors. During the experiment, an emphasis was

placed on precise planning, students' work in groups, appropriate arrangement of the classroom, and planning students' experimental work. Also, the expectations of the students in the experimental group differed from those of students in the control group. Taking part in the experiment and expectations from inquiry-based education were highly motivating as well, which is in line with other authors' findings [42, 43]. Students were the main actors in the educational process and the teacher had the role of a facilitator.

Another important phenomenon related to inquiry-based teaching was that students were not afraid of errors or mistakes as it is a concept of looking for alternatives. Inquiry-based instruction does not lead students to meeting goals directly, and so, errors are not perceived as something negative, but as an opportunity to find new alternatives. Students learn how to work with errors and mistakes and develop critical thinking. As pointed out by some authors in their studies, the main unit of knowledge in applying an inquiry-based approach is not facts, but methods, procedures, and processes [44].

The obtained results are consistent with the findings by Lederman et al. [45], Shami [46], Straits and Wilke [47], Apedoe and Reevs [48], Hodson [49], and Nuangchalerm and Benjaporn [50]. The presented findings show that, alongside the development of the ability to search and discover, inquiry-based teaching also has a statistically significant positive impact on increasing students' intrinsic learning motivation, which is in line with the findings presented in the PRIMAS [51] and MASCIL [52] reports. In accordance with Škoda et al. [53], it can be assumed that inquiry-based teaching cannot be considered a universal method of teaching and teachers' should adapt the applied inquiry-based activities to students' characteristics. During the experiment, several shortcomings were observed in the ways of students' inquiry assessment, which is a field that needs to be improved. Similar findings were presented by Chinn and Malhotra [54] or Deborah et al. [55].

6- Potentials and Limits of Inquiry-Based Education

Inquiry-based education appears to be a promising concept for improving teaching technical disciplines. Its potentials are as follows:

- Students' learning is spontaneous, inquiry-based education has a strong motivating effect;
- The developed knowledge appears to be more permanent compared with traditional teaching;
- Inquiry-based activities carried out by the students participating in the research were accompanied by intensive experiences, which was motivating as well;
- Inquiry-based activities allow students to be more active than traditional methods of teaching;
- Students can apply own strategies and meta-strategies of learning they spend more time by learning independently than by being taught by the teacher;
- Inquiry-based activities strengthen students' skills in the cognitive, as well as social and emotional fields;
- Students master the standard procedures and strategies of research;
- It is a flexible and adaptable teaching model.

Although there are undoubtable potentials of inquiry-based teaching, the fact that this concept has several shortcoming representing barriers to its broader application should be considered as well:

- Lesson planning is more demanding and undergraduate teacher-training can be considered insufficient in this field – teachers' ability to ask appropriate questions and to manage students' inquiry-based activities is decisive from the aspect of success or failure of inquiry-based instruction;
- The decision about implementing inquiry-based activities is influenced by the availability of equipment in schools;
- The participating teachers reported low levels of teachers' competencies in the field of carrying out inquiry-based lessons.

7- Conclusion

The main goal of the study was to find out whether inquiry-based learning leads to better knowledge acquisition, increased activity, and higher motivation levels in students compared with traditional learning, where students work according to an established procedure. We were also interested in students' educational pathways and aimed to identify the existing or potential barriers to inquiry-based teaching. By means of a pre-test and a post-test, the impact of two types of teaching on 6th grade students' results was compared. The results proved the existence of statistically significant differences according to the type of teaching in all observed fields. It can be assumed that while using the methods of inquiry-based teaching, an increased intensity of social interactions between students was observed, especially when sharing their thoughts and ideas. Also, the students' motivation levels were higher, and the quality of teamwork increased

as well. It was found that using some elements of inquiry in the classroom has a significant impact on all the observed fields of students' ability development. It can be assumed that the presented results confirmed the earlier findings of the above-cited international studies.

Although – due to the limits of the research study given by the size of the research sample and its composition – the presented findings cannot be generalized to the whole population of Slovak students, we believe that they can be considered significant, especially in the context of the trend of implementing activating methods in education and promoting experiential learning.

Taking into account the situation in the Slovak school system and the results of TALIS 2018 [56], the importance and the need for developing teachers' skills and competencies rooted in the theoretical knowledge of psychological and pedagogical sciences must be pointed out. The presented findings also have the potential to contribute to improving the quality of the educational process not only in technical education but in other fields of didactics as well.

The study offers implications for further research; the presented findings should be supported by further investigation in the field. The effect of inquiry-based teaching not only on students' further ability development but also on teachers' personalities should be focused on, as teachers themselves are the main initiators of this concept of teaching.

8- Declarations

8-1-Author Contributions

Conceptualization, M.K., J.S., and S.B.; methodology, M.K., J.S., and S.B.; writing—original draft preparation, M.K., J.S., and S.B.; writing—review and editing, M.K., J.S., and S.B. All authors have read and agreed to the published version of the manuscript.

8-2-Data Availability Statement

The data presented in this study are available on request from the corresponding author.

8-3-Funding

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8-4-Institutional Review Board Statement

Not applicable.

8-5-Informed Consent Statement

Informed consent was obtained from all individual participants included in the study.

8-6- Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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