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Research of correlation of theoretical knowledge and psychomotor skills of pupils in technical education

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A R T I C L E I N F O

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A B S T R A C T

The authors of the scientific study examine the impact of the relationship of theoretical knowledge on practical skills in technical subjects at the lower secondary level of education in the Slovak Republic. After determining the research problem and hypotheses, they bring the processed results in the form of tables and graphs. Quantitative results within the pedagogical experiment are supplemented by qualitative analysis. At the end of the scientific study, the authors compare the results ascertained from previously published information in the field of science.

1. Introduction

At present, technical education is one of the important and priority areas in our society. Effective solution of technical problem tasks requires a fundamental acquisition of theoretical knowledge and practical skills in lower, upper secondary education and at universities. Knowledge is memorized and learned facts, rules, and axioms. "Learned" means accepted by senses, understood and subjectively processed and fixed information, systems of ideas and concepts, rules, axioms, laws, definitions, theories. Educants acquire findings that become knowledge only when they acquire them. Skills are acquired readiness to perform correctly, as quickly as possible and with the least possible effort, a certain activity on the basis of acquired knowledge and previous practical activities. It can be a manual skill or an intellectual skill. In practice, we recognize motor and intellectual skills. The aim of the research is to find out how the 7th grade students are able to apply the acquired theoretical knowledge in solving practical problem tasks.

2. Definition of the research problem

We specify our research problem as a relational research problem: What is the impact of theoretical knowledge on solving technical problem tasks for students in lower secondary education. With this research problem formulated, we aim to determine the relationship between the phenomena being investigated (acquired theoretical knowledge in the subject of technology) and find out what their impact is on the effective solution of technical problem tasks. It is about explaining the relationship by cognitive processes and psychomotor skills in solving problem tasks at the level of learning specific and non-specific transfer according to Niemierk's taxonomy of educational goals. From the methodological point of view, we focus on the implementation of quantitative research, where we determine the relationship between the phenomena through research methods and tools. For quantitative research, we use observation sheets, where we record correct and incorrect answers of students. We also use mathematical-statistical methods to determine statistically significant differences among schools in individual regions in the Slovak Republic. We conceive research conclusions and findings into a new theory with regard to the needs of practice. Within the methodology of quantitative research, it is a branch of statistical analysis, where we focus our attention on monitoring the correct answers of students in solving practical problem tasks. We investigate how students can apply theoretical knowledge in solving practical problem tasks in the subject of technology.

3. Selection and characteristics of the research sample

The research was carried out during the school year of 2019/2020 at 10 primary schools in the Slovak Republic. Two primary schools were from the Žilina Region, 3 primary schools were from the Banská Bystrica Region, 3 primary schools were from the Prešov Region, 2 primary schools were from the Nitra Region. The selection of the research sample was subject to deliberate selection. Based on the available possibilities and with regard to the efficiency and economy of the research, we selected the pupils of the 7th grade of primary schools. Chráska (2007) states that the extent of the selection of the number of respondents can be empirically estimated by determining its minimum and maximum value according to the relationships:

$$n_{min} = 0.1\sqrt{n} \text{ and } n_{max} = \sqrt{n}$$

Where n is the total number of elements in the basic group. In our case, according to the Statistical Yearbook, the basic groups of 15 September 2018 had a range of n = 41.046 pupils in the 7th grade of primary school. According to the above

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relationships, the interval of our selection group should be within a range of 20 to 203 students. The selection group in our research consisted of n = 120 pupils in the 7th grade of primary schools. From the Žilina and Nitra Regions 30 pupils (a total of 60 pupils) were included in the research sample, and from the Banská Bystrica and Prešov Regions 30 pupils (a total of 60 pupils) were included in the research sample.

4. Research procedure

The practical part of the research was carried out as follows:

- We prepared 5 research problem tasks that contained unknown elements. Based on the acquired and known knowledge, the students had to practically solve the assigned problem tasks. The tasks were intended for pupils in the 7th grade of primary schools.
- Before starting the research itself, we carried out a pilotage, during which we got acquainted with the conditions in selected classes of the 7th grade. After consulting with a technical teacher, we selected the research participants. We selected a total of 100 students of the same performance level.
- We started to carry out the research with a research sample of 100 pupils who attend the 7th grade of primary schools. In total, we implemented 5 research units, which lasted a total of 15 teaching units.
- As part of the research, we applied the prepared tools for stimulating the cognitive functions of the student and tools for developing various levels of understanding of theoretical knowledge.
- Following the acquaintance with individual theoretical knowledge, students began to solve practical tasks in the subject of technology.
- The course of the research was recorded in observation sheets. Subsequently, we made well-arranged tables from the data in the form of observation sheets, where we present the correct and incorrect answers of all students included in the research sample.
- In the next part of the research, we compared the differences between students in individual regions using mathematical-statistical methods.

5. Research results

Table 1
Evaluation of solving practical tasks. (Legend: R – right solution, W – wrong solute)

Problém task	Solution options	7th grade students			
		ZA	PO	BB	NR
Problem task No. 1 Coat hanger	Technical sketch or technical drawing	R (20) W (10)	R (16) W (14)	R (15) W (15)	R (19) W (11)
	Measurement and contouring	R (21) W (9)	R (18) W (12)	R (17) W (13)	R (22) W (8)
	Drilling	R (20) W (10)	R (21) W (9)	R (22) W (8)	R (24) W (6)
	Cutting	R (23) W (7)	R (20) W (10)	R (21) W (9)	R (16) W (14)
	Sawing	R (27) W (3)	R (24) W (6)	R (16) W (14)	R (23) W (7)
	Bending	R (23) W (7)	R (21) W (9)	R (21) W (9)	R (22) W (8)
Problem task No. 2 Christmas decoration bell	Technical sketch or technical drawing	R (20) W (10)	R (19) W (11)	R (18) W (12)	R (21) W (9)
	Measurement and contouring	R (21) W (9)	R (20) W (10)	R (23) W (7)	R (22) W (8)
	Drilling	R (23) W (7)	R (22) W (8)	R (21) W (9)	R (21) W (9)
	Cutting	R (15) W (15)	R (16) W (14)	R (15) W (15)	R (21) W (9)
	Grinding	R (24) W (6)	R (18) W (12)	R (18) W (12)	R (14) W (16)
Problem task No. 3 Product - design	Technical sketch or technical drawing	R (24) W (6)	R (24) W (6)	R (23) W (7)	R (21) W (9)
	Measurement and contouring	R (21) W (9)	R (20) W (10)	R (23) W (7)	R (22) W (8)
	Other work operations (shearing, bending, etc.)	R (20) W (10)	R (21) W (9)	R (19) W (21)	R (21) W (9)
Problem task No. 4 Pen stand	Measurement and contouring	R (26) W (4)	R (25) W (5)	R (27) W (3)	R (28) W (2)
	Right choice of tools and implements	R (27) W (3)	R (24) W (6)	R (27) W (3)	R (19) W (11)
	Cutting	R (20) W (10)	R (22) W (8)	R (23) W (7)	R (21) W (9)
	Drilling	R (23) W (7)	R (24) W (6)	R (24) W (6)	R (24) W (6)
	Bending	R (28) W (2)	R (27) W (3)	R (28) W (2)	R (26) W (4)
Problem task No. 5 Set square	Technical sketch or technical drawing	R (22) W (8)	R (21) W (9)	R (22) W (8)	R (24) W (6)
	Material selection	R (28) W (2)	R (29) W (1)	R (30) W (0)	R (27) W (3)
	Right choice of technological procedure	R (21 W (9)	R (24) W (6)	R (26) W (4)	R (24) W (6)
	Total number of responses	660	660	660	660
	Number of correct answers	497	476	479	482
	Number of incorrect answers	163	184	181	178

The detailed analysis of individual students' answers by region is given in Table 1. Further, we present the complete wording of the task and a brief analysis of students' individual answers by region.

6. Analysis of students' answers

Problem task No.1: The students had the task to design a sketch or technical drawing of the hanger product. Then they had to make it correctly.

The technical sketch or technical drawing was correctly designed by 70 students out of a total of 12 students, which represents 58%. The students mostly designed a technical sketch. We see the problem in the weaker or insufficient acquisition of knowledge from graphic communication. It was difficult for pupils to imagine the developed shape of the hanger, its representation and especially the correct dimensioning of the product. Pupils from the Žilina and Nitra Regions best solved this part of the task. The second part of solving the task was focused on making the designed product. Pupils had the biggest problems with transferring dimensions from a technical sketch or drawing to material. Most students (80%–90%) correctly chose and performed work operations.

It follows from it that although the students have gained knowledge from graphic communication, but in practice they are not able to apply it to solve practical tasks. Other necessary theoretical knowledge can be effectively applied by them in the manufacture of practical products, in this case a metal product - hanger.

Problem task No.2: The students had the task to design a wooden Christmas decoration, then to make it. The emphasis was on the right choice of work operation.

The technical sketch or technical drawing was correctly designed by 65% of students. Students designed a technical sketch. Compared to the first task, the students achieved higher performance in the design of the technical sketch. We think that students have a better idea of Christmas decorations. They could imagine the shape of a Christmas decoration. They designed bells, stars, snowflakes, etc. Regarding the choice of the right work operation, we can say that 72% of students were also able to transfer the dimensions from the sketch to the required material. Only 27% of students had a problem making a hole in the material. The students were helped by the teachers to drill, which is also why the pupils managed this work operation at the required level. More than half of the students (56%) managed to work with a hand saw (dovetail or cap). Quite a lot of students were not able to work with a hand saw or had problems with cutting. We consider insufficient acquisition of theoretical knowledge and insufficient practice of working with hand saws as one of the reasons for this unfavorable situation. During the last work operation, the students adjusted the product to its final form. Almost 62% of students correctly held sandpaper in their hands and then performed the required operation in the right way. Here it is also necessary to devote more space to the use of the correct terminology (emery, correct sandpaper). When making this product, the students applied mainly work operations focused on the chip machining of technical materials (in our case wood). More attention needs to be paid to practicing work operations such as cutting, grinding, but also drilling.

Problem task No.3: The students had the task to design and make any product from steel sheet with a thickness of 0.5 mm and dimensions of 120 x 100 mm.

In solving this problem task, the students were very attentive and were able to design various sheet metal products. Pupils designed various animals (weasel, frog, tree, various logos, etc.). Almost 77% of students managed the first part of the task at the required level and without mistakes. When measuring and transferring dimensions from a sketch or drawing, almost 28% of students were not able to correctly transfer dimensions from a technical sketch or drawing to material. Here it is necessary to devote more time with students to repeating and consolidating the curriculum from graphic communication. Regarding the correct use of other work operations (shearing, bending, drilling), we can state that students managed them correctly in 68%. Here we also see space for more frequent repeating and practicing of work operations (especially shearing). Finally, we evaluate students positively in solving this problem task, a larger number of students understand the acquired knowledge and are able to apply theoretical knowledge in the manufacture of any product.

Problem task No.4: According to the acquired theoretical knowledge, students should be able to transfer the dimensions from the designed technical drawing, choose the right tools and select the right technological procedures needed to make the product.

The task was focused on a specific transfer according to Niemierk's taxonomy of educational goals. In this case, the students received an already designed technical drawing. Their task was to correctly transfer the dimensions from the technical drawing to the material. Then they continued to choose the right work operation and the necessary work tools and implements. We evaluated three parts of the making of the designed product. 88% of students managed the measurement and contouring. In this case, the students no longer designed the shape and dimensions of the product. They only had to transfer the finished dimensions to the material being processed. Pupils did this part of the task best. The next part of the task was focused on the correct choice of work tools and implements. Only 19% of students made mistakes in the correct selection and use of work tools and implements. We state that even this part of the practical task was solved correctly by more students. In the last phase of solving the task, students were evaluated on the basis of the correct implementation of work operations. Pupils cut, drilled and finally bent the product being made. In most cases, the students managed the first two operations at the required level. The teachers helped them to bend, as the plastic had to be heated above the flame. We also evaluate the managing of the last phase of the product manufacturing positively. Students still have minor shortcomings in the acquired theory. Elimination of the mentioned shortcomings is possible with more frequent repetition, consolidation and deepening of the acquired curriculum.

Problem task No.5: The students had the task to design a technical sketch or technical drawing of a specific product and then make a simple product – a set square. Then they had to choose a suitable material and design a technological procedure of making the product.

In most cases (74%), students correctly designed a specific assigned product – a set square. Most students chose wood or metal as the material, which was the right procedure. Only a few students wanted to make a plastic set square, which we do not consider to be the right procedure. We also evaluated the correct choice of technological procedure. Only 21% of students suggested incorrect technological procedure of making the product. We confirm that students have the acquired knowledge at the required level, but they still have a problem applying this theoretical knowledge in solving, making a practical product. This shortcoming can be eliminated not only by more frequent repetition of the curriculum, but also by solving several practical tasks, where students try out the necessary work operations to make various designed or assigned products.

Subsequently, we tested the established hypotheses at the level of significance α= 0.05 (95%).

H0: The results achieved by students from the Žilina, Prešov, Banská Bystrica and Nitra Regions in solving practical problem tasks will be the same.

H1: Pupils of the Žilina Region will achieve higher performance in solving practical problem tasks in comparison with pupils of the Prešov Region.

H2: Pupils of the Žilina Region will achieve higher performance in solving practical problem tasks in comparison with pupils of the Banská Bystrica.

H3: Pupils of the Žilina Region will achieve higher performance in solving practical problem tasks in comparison with pupils of the Nitra Region.

H4: Pupils of the Žilina Region will achieve higher performance in solving practical problem tasks in comparison with pupils of the Prešov Region.

H5: Pupils of the Banská Bystrica Region will achieve higher performance in solving practical problem tasks in comparison with pupils of the Prešov Region.

H5: Pupils of the Banská Bystrica Region will achieve higher performance in solving practical problem tasks in comparison with pupils of the Nitra Region.

H5: Pupils of the Prešov Region will achieve higher performance in solving practical problem tasks in comparison with pupils of the Nitra Region.

We were interested in what performances students achieve when solving problem tasks in the subject of technology. By solving practical tasks correctly, the student could get a maximum of 22 points of gross score (gs) while solving 22 partial practical tasks. From the descriptive statistics (Table 2) it is clear that students mastered the curriculum at an above-average level. The calculated arithmetic mean and standard deviation for pupils from the Žilina, Prešov, Banská Bystrica and Nitra Regions were calculated on the confidence interval: lower interval: -95%, upper interval: +95%. From the mean obtained from the measured research sample we derive the information that the calculated arithmetic mean for pupils from the Žilina Region is from the measurement confidence interval from 15.74 to 17.40, for pupils from the Prešov Region from the measurement confidence interval from 14.99 to 16.74, for pupils of the Banská Bystrica Region from the measurement confidence interval from 15.19 to 16.75 and for pupils of the Nitra Region from the measurement confidence interval of 15.38 to 16.75. We can say that the students solved the practical problem tasks at about the same level. Pupils from the Žilina Region achieved the best mean. The variation range for pupils in the Žilina Region is determined by a minimum value of 10 and a maximum value of 19, for pupils in the Prešov Region it is determined by a minimum value of 10 and a maximum value of 18, for pupils in the Banská Bystrica Region it is determined by a minimum value of 11 and a maximum value of 19, and for pupils in the Nitra Region the variation range is determined by a minimum value of 12 and a maximum value of 19.

The median for pupils of the Žilina Region was calculated to be 18, for pupils of the Prešov Region 16, for pupils of the Banská Bystrica Region 16 and for pupils of the Nitra Region 16. Thus, half of the pupils of the Žilina Region achieved performance in solving practical problem tasks (PPT) ≤ 18 points and the other half of the pupils achieved performance in solving practical problem tasks (PPT) ≥18 points, also one half of pupils from the Prešov, Banská Bystrica and Nitra Regions achieved performance in solving practical problem tasks (PPT) ≤ 16 points and the other half of pupils achieved performance in solving PPT ≥ 16 points. Also, from the descriptive statistics we can say that the peak coefficient is not equal to zero and therefore we state that the distribution of values is more pointed (asymmetrical) than the normal distribution of values.

Banská Bystrica and Nitra Regions it is equal to 16. The median is the mean value that divides the respective series of values into two approximately equal halves. In the case of a symmetrical distribution of values, the median is the same as the mean. In our case, we found out that the calculated arithmetic mean and median are not the same. We measured the deviations of the median from the mean very small, for all students from all regions. The interquartile range represents the area of the mean 50 percent of the values of the variables, i. e. for pupils of the Žilina Region from 13 to 19, for pupils of the Prešov Region from 10 to 18, for pupils of the Banská Bystrica Region from 12 to 19, and finally for pupils of the Nitra Region from 13 to 18. The interquartile range is the difference between the third and first quartiles (the 75th and 25th percentiles). The interquartile range is important in determining the so-called outliers. In our case, we found out that in addition to the group of students from the Žilina and Prešov Regions, there were few outliers outside the interval (interquartile range) in other research groups.

Table 2
Descriptive (basic) statistics.

Variables	ZA	PO	BB	NR
Valid data	30	30	30	30
Missing data	0	0	0	0
Sum	497	476	479	482
Mean	16.57	15.87	15.97	16.07
Variance	4.94	5.50	4.38	3.37
Standard deviation	2.22	2.34	2.09	1.84
Variance coefficient	0.13	0.15	0.13	0.11
Standard error of mean	0.41	0.43	0.38	0.34
Upper 95% CL of mean	17.40	16.74	16.75	16.75
Lower 95% CL of mean	15.74	14.99	15.19	15.38
Geometric mean	16.40	15.68	15.83	15.96
Skewness	-1.05	-1.01	-0.30	-0.24
Kurtosis	3.49	3.42	2.47	2.06
Maximum	19	18	19	19
Upper quartile	18	18	18	18
Median	18	16	16	16
Lower quartile	15	15	15	15
Interquartile range	3	3	3	3
Minimum	10	10	11	12
Range	9	8	8	7
Centile 95	19	18	19	18
Centile 5	13	10	12	13

Table 3
Kruskal-Wallis test.

Variables: ZA, PO, BB, NR
Groups = 4
df = 3
Total observations = 120
T = 2.077314
P = 0.5565
Adjusted for ties:
T = 2.225042
P = 0.527

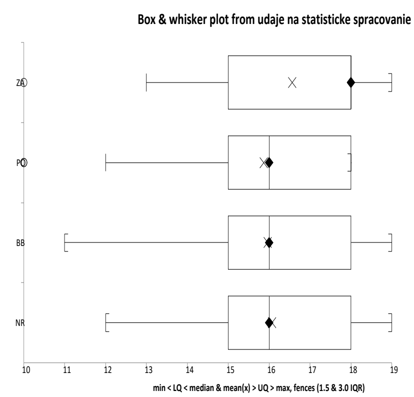

Fig. 1. Median, quartile and variational range of variables from solving practical tasks in the 7th grade students.

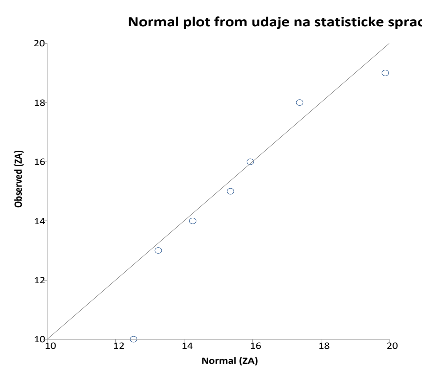

Fig. 2. Evaluation of the normality of random errors - graph of the normality of residues in the research group (ZA Region).

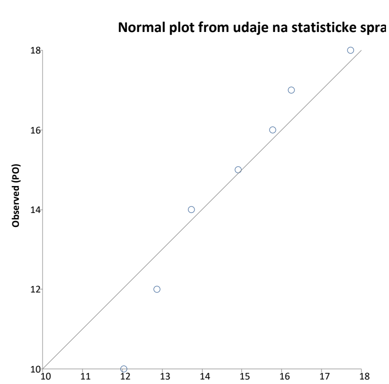

Fig. 3. Evaluation of the normality of random errors - graph of the normality of residues

Table 4
Kruskal-Wallis test:all comparisons(Dwass-Steel-Chritchlow-Fligner).

Critical q (range) = 3.63316	
ZA vs PO (|-1.95048| > 3.63316)	not significant p = 0.5124
ZA vs BB (|-1.506391| > 3.63316)	not significant p = 0.7108
ZA vs NR (|-1.725646| > 3.63316)	not significant p = 6.140
PO vs BB (|0.085939| > 3.63316)	not significant p = 0.9999
PO vs NR (|0.108066| > 3.63316)	not significant p = 0.9998
BB vs NR (|0.107133| > 3.63316)	not significant p = 0.9998

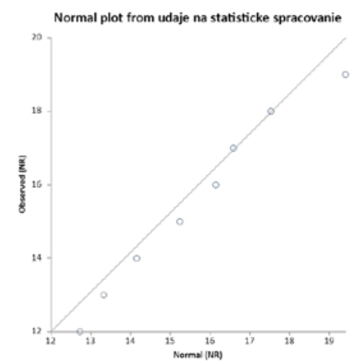

Fig. 4. Evaluation of the normality of random errors - graph of the normality of residues in the research group (BB Region).

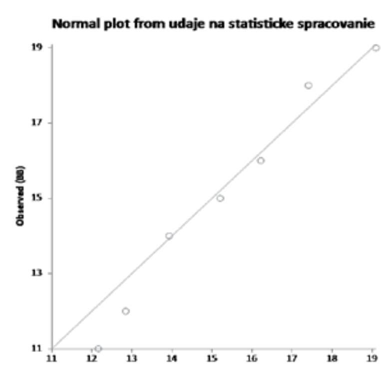

Fig. 5. Evaluation of the normality of random errors - graph of the normality of residues in the research group (NR Region).

Residue is the difference between the actual and estimated value. In our case, the residues have a normal distribution (Fig. 2 and Fig. 5), because the graph of the normality of residues created a line or the appearance of normal probability graphs is acceptable. We also decided to use the non-parametric test based on the met requirement (variances between the research groups are not equal). Based on the findings, we decided to use the non-parametric Kruskal - Wallis test (Table 3.4). We reject the null hypothesis if $H \geqslant \chi^{2}_{1-\alpha}(k-1)$. For the level of significance $\alpha = 0.05$, the rejection area is determined by the value of the quantile $\chi^{2}_{1-\alpha}(k-1) = \chi^{2}_{0.95}(1) = 3.63316$. This means that the value of the testing statistic is not in the area of rejecting the null hypothesis. We found out that the calculated p value is a too large value, i.e. that the hypothesis H0 was confirmed at the level of signi-ficance $\alpha = 0.05$ (95%). We also investigated whether there were also statistically significant differences between individual regions. This leads to the conclusion that the performances achieved by students from individual regions are not statistically different.

The calculated p value is too large, and thus we not only confirm the null hypothesis and in conclusion we can state that the hypotheses H1 and H6 were not confirmed. As the results of our research prove, the differences between pupils from individual regions are different from descriptive statistics, but further research finds out that there are no statistically significant differences between the performances of pupils from individual regions.

7. Discussion

Practical skills and solving technical problem tasks are of great importance in technical education. In order for a student to be able to have practical skills in solving various practical and problem tasks, he first needs to acquire quality theoretical knowledge. We can say that theory has the effect of acquiring the right practical skills and solving problem tasks. Through pedagogical research, we found out that the pupils of the 7th grade of primary school in individual self-governing regions acquired theoretical knowledge, but they show only minor shortcomings in solving technical problem tasks. We suggest that more emphasis be placed on assigning and solving technical problem tasks directly in the educational process in the subject of technology in lower secondary education. This attention needs to be paid already earlier in the technical education of children and pupils at pre-primary and primary level of education. The issues of acquiring skills in students in the psychomotor field have long been addressed by several experts. Professor Ján Bajtoš has published several scientific studies in this field. Not only did he develop taxonomy of educational goals in the psychomotor field, but he also elaborated and analyzed in detail the criteria for evaluating students' performance in the psychomotor field. This area of research in trade union didactics is important. Developing and shaping psychomotor skills is part of general education. Abroad, Flitner (1990) and Hurrelmann (1998) addressed the issue. Psychomotor skills can be acquired in various forms of teaching. In the subject of technology, they are: manual processing of technical materials, experimental activity (examination of basic properties of technical materials), etc. Teaching the subject of technology serves to develop the abilities and skills of students, which are necessary for various activities in their later lives, or for their future profession. Theoretical knowledge plays an important role, which can have a very significant effect on students' performance in the psychomotor field. Educators should have a positive effect on the performance of educants. To support educants in acquiring knowledge and skills through independent search, research and experimenting. It is important to focus more on the level of skill acquisition, use theoretical knowledge in practical activities, work skills. The teacher must make sure that the student is able to apply the acquired theoretical knowledge in practice, pay attention to the level of professional skills, so that his work skills are worthy of application in the labour market. Therefore, it is important that the teacher correctly evaluates and controls the student's readiness for teaching, quality and range of intellectual abilities and habits, motor skills, acquired knowledge and skills, activity, theoretical knowledge. The teacher should always focus on keeping students informed about what is expected of them during the lesson, otherwise their learning initiative will decrease. When evaluating psychomotor skills depending on the nature of the teaching process, it is also important to keep in mind a suitable choice of the level of taxonomy.

8. Conclusion

Effective employment of an individual in the modern labour market requires quality preparation of the individual at the contemporary school. It is the ability of an individual to solve technical problem tasks that is his guarantee for a successful application in practice. Theory and practical skills form the basis for such mastering of established problem tasks. In accordance with the requirements of society and modern trends, for technically oriented subjects it is necessary to create ideal conditions for their development and consolidation of their firm place in the school system. Effective education of students in the technical field at the lower level of secondary education and subsequent continuation at the upper level of secondary education is a guarantee of a possible prospective employment of an individual in the labour market. Qualitative acquisition of theoretical knowledge by students is also a guarantee for the effective acquisition of skills in students in the psychomotor field. The implemented pedagogical research shows that students achieved the same performance in solving practical tasks, between which there were no statistically significant differences. Pupils achieved very good results in solving tasks in the psychomotor area. We can say that they have very good theoretical knowledge, which allows them to solve practical technical tasks at the required level. In the future, we will also focus on finding out practical skills of students from all grades of lower secondary education so that our research sample is as large as possible. Then we will be able to generalize the evaluated results to the entire population of students at the contemporary school. This scientific publication was supported by the Scientific Grant Agency of the Slovak Republic VEGA within the framework of grant No. 1/0147/19.

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