Verification of the Impact of the Distance Education Program on the Development of Students' Skills

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***Abstract* – The authors present research focusing on the issue of technical education in the context of distance education. It deals with the development of psychomotor skills of students in a vocational subject during distance education. The research aimed to verify the impact of the designed distance education program on developing and enhancing students' skills in the subject of robotics. The sample consisted of 10 students. A pedagogical experiment was used as the research method. The findings show statistically significant changes in the students' skills in the posttest compared to the pretest. It was mirrored in higher values of the skill posttest results. The designed distance education program helped develop students' manual skills. The research results emphasize the importance of personal interaction and support in technical education. The paper was created as a part of the grant project VEGA No. 1/0550/22 Current state, trends, and problems in technical education at the lower and upper secondary education level concerning distance education.**

***Keywords* – Technical education, robotics, distance education, skill tests, pretests, posttests.**

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1. Introduction

Generally, technical education involves vocational and practical training of an individual for his future technical occupation. It should develop creative and technical thinking, the ability to use various tools and technical equipment, master technologies, and programs, and fully use creativity in everyday life. [1].

Vocational secondary schools play a crucial role in developing students' psychomotor skills through technical education. This type of education focuses on practical and technical areas, emphasizing manual skills and precision. It allows students to learn how to work with various tools and materials, significantly supporting the development of their psychomotor skills. Practical experience gained through exercises and projects within technical education helps develop students' skills and strengthens their ability to coordinate work with various tools and devices. Technical education at secondary vocational schools is also important, as it allows students to acquire practical experience and knowledge in technical fields, opening the door to many promising and well-paid job opportunities in technical industries.

According to the author [2], it is essential to strengthen the manual and technical skills of students and the young generation. Otherwise, the young generation could develop a psychological barrier and a reluctance to study technically oriented fields, leading to a loss of motivation to explore, develop, and innovate. After graduating from secondary school, students could opt for higher education at any university instead of studying demanding technical fields, possibly increasing the risk that they will not be able to apply themselves to the labor market.

The field of technical education, whether via face-to-face or distance education, is broad and covers education at the primary, lower, and upper-secondary levels, as well as technical universities.

Technical education has a long-standing tradition in the Slovak Republic, as evidenced by the sustained research interest of leading Slovak experts in technical education at both lower and upper secondary levels of specialist schools [3], [4], [5], [6], [7], [8], [9].

2. Distance Education in Technical Subjects

The education of technical subjects such as mechanical engineering, construction, information and communication technologies, robotics, programming, computer networks, and programming of LEGO robots can be effectively conducted remotely. Teachers in these fields make extensive use of online simulation environments to facilitate learning and practical activities. For instance, in the teaching of robotics, teachers utilize various platforms for intelligent 3D robot simulations, as well as applications like Tinker CAD and LOGO! Soft Comfort from SIEMENS. This allows students to virtually build and program robots and engage in practical activities online. However, a major challenge in technical education is that psychomotor learning objectives cannot be fully achieved through distance education. For instance, in robotics education, constructing a robot from a LEGO kit is an essential part of the curriculum, but not all students have access to such kits at home due to their cost. Similarly, students studying construction or mechanical engineering face obstacles as they are unable to work with equipment such as CNC machines or engage in hands-on activities under the guidance of an instructor. To address these challenges, schools may need to modify the curriculum and postpone teaching certain practical components when students can resume face-to-face learning.

The remote teaching of technical subjects poses several challenges, especially in developing the student's personality, particularly its conative component. This area primarily involves coordination between thoughts and movements, which is crucial for developing necessary technical skills. Distance education significantly limits the possibilities of implementing technical projects, which affects the support and development of students' skills. Physical supervision and the possibility of immediate feedback, coordination, demonstration, or instruction are also questionable. Virtual simulations cannot fully replicate real-world practice, and access to materials, tools, and technologies has proven problematic.

Considering the above facts, a distance education program designed for educators and students helps alleviate or eliminate these problems.

The program focuses on distance education in the subject of robotics, specifically mechanics and drives. It aims to support and develop manual skills.

The program comprises all the necessary instructions, tutorials, and diagrams for creating a robotic product. It is divided into two main parts: one for students and the other for teachers. Each part has its structure and content tailored to the needs of the specific target group. In the future, the designed distance education program will act as a manual for teachers during transitions to distance education or to help long-term ill students participate in blended learning. Blended learning allows students who are not physically present in the classroom to take part in the lesson and interact with the teacher and other students, while also enabling the teacher to maintain a certain level of control and coordination of education.

The effectiveness of the designed distance education program was experimentally verified.

3. Implementation of Experimental Verification

One of the main objectives of the extensive qualitative-quantitative research was to design, create, and experimentally verify the TechnoMind program for distance education. As part of this objective, hypothesis H1 was formulated: It is assumed that the TechnoMind program will positively impact the quality of education in the technical subject of robotics, leading to higher skill posttest results after implementing the intervention with the TechnoMind program.

Identification of variables in hypothesis H1:

independent variable: designed distance education program,

dependent variable: students' results in the skill posttest.

According to the author [8], psychomotor activities are integral to our lives. Their development is significant for the education and development of our personality. Acquiring work skills is not just a matter of mechanical drill, but primarily depends on intellect and motivation.

In collaboration with vocational subject teachers, a skills test was developed to assess students' practical skills and performance in specific vocational subjects. The test evaluated how well students managed tasks, activities, or procedures relevant to a technical field or profession. The test consisted of eight short practical tasks focusing on drawing and dimensioning simple parts, shaping wire, cutting out, screwing, assembling simple parts from 'L profiles' and LEGO bricks, and more.

The results of the practical skills test offered valuable insights into the students' practical skills and their quality.

During posttests, it was essential to avoid the unwanted effect known as "test-enhanced learning" or "retrieval practice". There would be a risk of students memorizing the technical procedures for solving the skills test tasks in the pretests, which could distort the results and show an artificial improvement or decline in performance due to memorization rather than a genuine change in the students' skills in the posttests. In response to the earlier issues, specific measures were implemented. These included different variations of the skills test tasks in the pretests and posttests, randomizing the order of assignments, allowing an adequate time gap between the pretests and posttests, and ensuring thorough monitoring and control during the measurements. The scheme of the experiment is shown in Fig. 1.

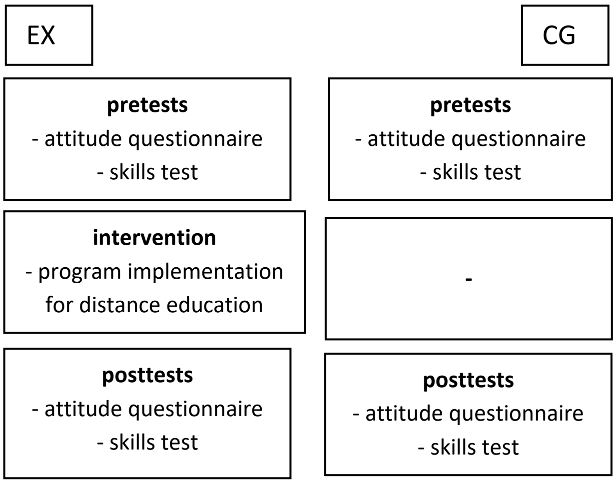

Figure 1. Schematic diagram of the experiment implementation

The research sample

Two groups of students from two classes at the same school, in the same grade, and studying the same field participated in an experimental verification. Each group, control and experimental, consisted of ten students. The total number of students was twenty.

During the experiment, there was an effort to minimize or eliminate any intervening variables. It was significant to ensure that both groups were equal based on predetermined criteria to reduce the influence of these variables on the experiment results. The control and experimental groups were similar in terms of size (number of students), students' age, gender, previous assessments, and educational outcomes.

Additionally, students in both groups had similar school attendance, and subject lessons were scheduled for both groups at the same time and day.

Both groups had teachers with the same professional competencies, and the students were equally motivated to participate in the experiment. The students were divided evenly based on their family backgrounds, including socioeconomic status. A favorable working environment was established to minimize stress levels. The students had the same or similar health conditions, and both groups were equally divided in terms of nationality and culture to reduce or eliminate the influence of intervening variables on the experiment results as much as possible.

Interpretation of control group skill test results

After completing the experimental verification, skill posttests were conducted in both the control and experimental groups, as shown in Figure 1.

The Wilcoxon test assessed the values between the pretest and the posttest to determine if there were statistically significant changes [10]. The results of the Wilcoxon test between the pretest and the posttest for the control group's students' skills are presented in Table 1.

Table 1. Results of the Wilcoxon test when measuring skills in the control group between the pretest and the posttest

Subtest	PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8
Monte Carlo Sig. P-values	0.002	0.213	0.156	0.499	0.033	0.046	0.096	0.114

Legend: the PT1 – subtest focused on component dimensioning, the PT2 - subtest focuses on working with hydraulics, the PT3 - subtest focuses on constructing a cross frame, the PT4 - subtest focuses on wire shaping, the PT5 - subtest focuses on constructing a LEGO chassis, the PT6 - subtest focusing on constructing a LEGO gear, the PT7 - subtest focused on screwing, the PT8 - subtest focusing on cutting out.

The Monte Carlo Sig. P-values of the Wilcoxon test (Table 1) indicate that at the selected significance level α = 0.1, there are statistically significant differences between the pretests and posttests of the control group in four out of eight subtests when measuring skills. These subtests are focused on component dimensioning (PT1), constructing a LEGO chassis (PT5), building a LEGO gear (PT6), and screwing (PT7).

Descriptive characteristics, such as mean, standard deviation, minimum, and maximum [10], provided a more accurate interpretation of the results between skills pretests and skills posttests within the control group. These characteristics are presented in Table 2.

Table 2. Descriptive characteristics when measuring skills in the control group between pretest and posttest

Sub test	Mean		Std. Deviation		MIN		MAX	
	Pre test	Post test	Pre test	Post test	Pre test	Post test	Pre test	Post test
PT1	104,80	61,50	21,877	13,327	72	46	147	88
PT2	15,00	17,50	5,249	3,749	9	13	24	24
PT3	2,50	3,30	1,509	1,494	0	0	4	4
PT4	19,70	20,30	9,534	8,525	0	2	28	29
PT5	2,10	3,60	2,025	0,699	0	2	4	4
PT6	3,00	1,60	1,633	1,897	0	0	4	4
PT7	240,10	213,10	53,163	36,014	156	128	332	255
PT8	7,80	9,90	2,098	3,178	6	6	12	18

Legend: *Mean - average value, Std. Deviation - standard deviation, MIN - minimum value, MAX - maximum value, red color - deterioration of results, green color - improvement of results*

The graph in Figure 2 shows the average values of times and points from individual subtests that the control group students achieved when measuring skills in pretests and posttests.

Figure 2. Average values of times and points achieved in subtests by the control group students when measuring skills in pretests and posttests

Legend: *subtest PT1 (time), subtest PT2 (time), subtest PT3 (points), subtest PT4 (points), subtest PT5 (points), subtest PT6 (points), subtest PT7 (time), subtest PT8 (points)*

The analysis of the descriptive indicators reveals that students in the control group improved their skills in the posttests, specifically in component dimensioning (PT1) and screwing nuts (PT7). The average time needed by the students to dimension the machine component and to correctly screw in the nuts decreased in the posttests. Additionally, students in the control group showed improvement in constructing the chassis mechanism from LEGO parts (PT5) in the posttests.

However, they demonstrated less skill in creating a simple belt drive from LEGO parts (PT6) and also exhibited a decrease in average points obtained. There was a slight improvement in the students' skills in the posttests in the other three subtests: constructing a cross frame (PT3), wire shaping (PT4), and cutting (PT8). In the subtest focused on working with hydraulics (PT2), the control group students were less skilled in the posttests than in the pretests.

Interpretation of experimental group skill test results.

In the experimental group, the Wilcoxon was used to compare the values between pretests and posttests. The results are displayed in Table 3.

Table 3. Results of the Wilcoxon test for measuring skills in the experimental group between the pretest and the posttest

Subtest	PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8
Monte Carlo Sig. P-values	0.002	0.466	0.010	0.213	0.502	0.494	0.005	0.001

Legend: *the PT1 – subtest focused on component dimensioning, the PT2 - subtest focuses on working with hydraulics, the PT3 - subtest focuses on constructing a cross frame, the PT4 - subtest focuses on wire shaping, the PT5 - subtest focuses on constructing a LEGO chassis, the PT6 - subtest focusing on constructing a LEGO gear, the PT7 - subtest focused on screwing, the PT8 - subtest focusing on cutting out.*

Table 4 provides descriptive characteristics for interpreting the skill results.

Table 4. Descriptive characteristics for measuring skills in the experimental group between pretest and posttest

Sub test	Mean		Std. Deviation		MIN		MAX	
	Pre test	Post test	Pre test	Post test	Pre test	Post test	Pre test	Post test
PT1	140,30	76,30	38,445	28,667	94	44	216	132
PT2	20,50	20,20	6,671	6,746	12	10	31	32
PT3	1,40	3,20	1,075	1,476	0	0	4	4
PT4	14,30	17,00	9,019	7,846	0	5	25	30
PT5	3,30	3,50	1,494	0,972	0	1	4	4
PT6	2,70	2,60	1,703	1,506	0	0	4	4
PT7	243,20	187,10	67,967	57,588	154	59	355	259
PT8	4,40	10,20	1,506	3,225	3	6	6	15

Legend: *Mean - average value, Std. Deviation - standard deviation, MIN - minimum value, MAX - maximum value, red color - deterioration of results, green color - improvement of results*

Additionally, Figure 3 illustrates the average values of times and points from individual subtests that students in the experimental group achieved when measuring skills in pretests and posttests

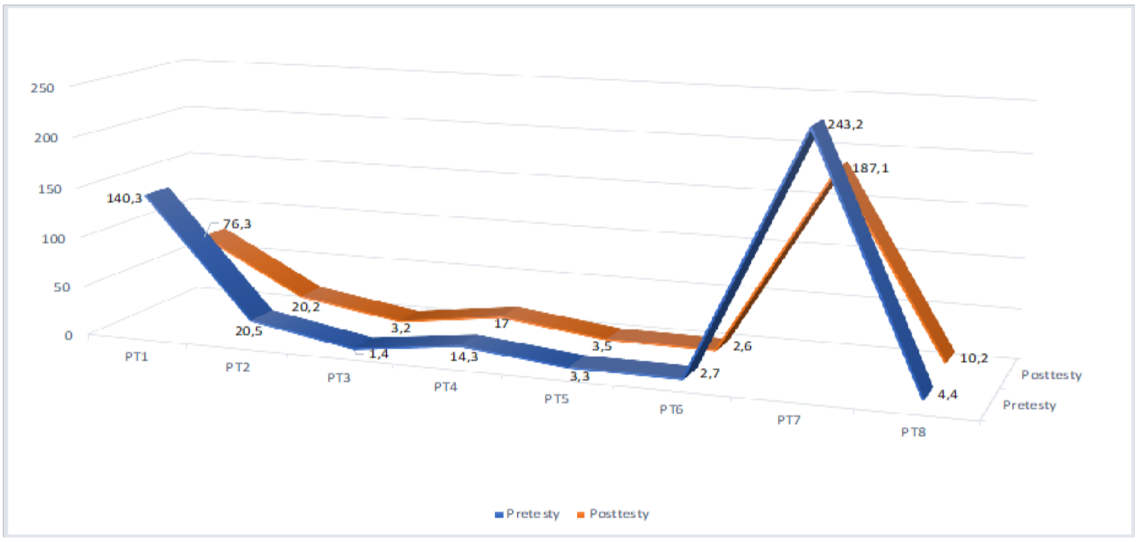

Figure 3. Average values of times and points achieved in subtests by experimental group students when measuring skills in pretests and posttests

Legend: *subtest PT1 (time), subtest PT2 (time), subtest PT3 (points), subtest PT4 (points), subtest PT5 (points), subtest PT6 (points), subtest PT7 (time), subtest PT8 (points)*

The Monte Carlo Sig. P-values of the Wilcoxon test (Table 1) indicate that at the selected significance level $\alpha = 0.1$, there are statistically significant differences between the pretests and posttests of the experimental group in four out of eight subtests when measuring skills. These subtests are focused on component dimensioning (PT1), constructing a cross frame (PT3), screwing (PT7), and cutting out (PT8).

The first subtest evaluated the students' ability to dimension components. The students showed improvement as the average time required to dimension the component correctly decreased from [AM 140.30] to [AM 76.30] in the posttests, indicating a 45.61% improvement, while taking into account the lower the time to perform dimensioning, the better the skills of the students. This change suggests that the students' skills have significantly improved in this area throughout the tests, which can be considered statistically significant based on the results.

The second subtest measured students' skills in working with hydraulic components. There was only a slight improvement in the students' skills in working with hydraulics in the posttests. They achieved an average time of [AM 20.20], representing a decrease of [AM 0.30]. This change is slightly positive. However, it cannot be considered statistically significant.

In the third subtest, students constructed a simple cross frame using 'L' profiles, screws, and nuts. The results showed a significant improvement in the students' skills in the posttests compared to the pretests. The average values for the pretests and posttests were [AM 1.40] and [AM 3.20] respectively, indicating a significant change. The increase of points gained by [AM 1.80] is very positive, indicating significant improvement in constructing the cross frame by the experimental group students.

The fourth subtest focused on measuring the students' skills in wire shaping, and they achieved an average of [AM 17] points in the posttests. This represents an improvement of [AM 2.70] points, indicating a positive change and significant improvement in the students' wire-forming skills.

Subtests 5 and 6 assessed students' abilities in working with Lego kits. The tasks involved building the chassis and gear using Lego parts. When comparing the average scores, the difference between the pretests and posttests in chassis construction is positive but relatively small and not statistically significant. However, the students' results when constructing Lego gear were not positive. In the pretests, they scored [AM 2.70] points and [AM 2.60] points in the posttests, indicating a decrease of [AM 0.10] points. This change is slightly negative and also not statistically significant.

This finding is surprising and unexpected, especially considering that one of the crucial units in robotics education, in face-to-face courses, focuses on constructing robotic products from LEGO components. Based on the information provided, several factors could hinder students' ability to build with LEGO parts. Some possible reasons could include a lack of experience with LEGO pieces, which may have made students feel less confident when using and handling them. If students have not had enough opportunities to practice these skills, their performance may improve slowly. Another reason could be the absence of motivation, which is crucial for improvement. If students are not motivated or interested in LEGO, this can affect their performance. In personal interviews, students revealed that more than half of them had hardly played with Lego in their childhood or not at all. It follows - if students had regular opportunities to work, practice, and construct with LEGO parts, they could repeat and refine their skills. It is essential to provide students with different tasks that stimulate various aspects of their abilities, create motivating and relevant tasks to stimulate interest and motivate students, and encourage creativity and fun in construction so that students feel engaged and have fun while learning. It can support their all-round development.

The seventh subtest determined students' skills at screwing nuts. The average time required to screw the nuts onto the correct bolts decreased in posttests to [AM 187.10]. It represents a time reduction of [AM 56.10]. Therefore, the students have shown improvement in their nut-screwing skills. The ability to bolt and screw nuts onto the correct bolt has several important implications for education and practical skills.

The final subtest evaluated students' ability to cut out geometric shapes. Statistically, there was a significant improvement in students' skills in the posttests. Comparing the average scores, the change between the pretests [AM 4.40] and the posttests [AM 10.20] is highly significant. The improvement signifies an increase of up to [AM 5.80] points. This change reflects a positive outcome, indicating that students in the experimental group significantly enhanced their skills in cutting out geometric shapes from paper.

The assumption formulated in hypothesis H1 - the TechnoMind program will positively impact the quality of education in the technical subject of robotics, leading to higher skill posttest results after implementing the intervention - was confirmed.

The assumption is supported by statistical analysis of data from experimental verification (shown in Table 4).

The students in the experimental group showed improvement in seven subtests in the posttests (PT1-76.30, PT2-20.20, PT3-3.20, PT4-17.00, PT5-3.50, PT7 -187.10, PT8-10.20), with higher scores and better time values for individual tasks. Statistically significant changes were observed in three subtests, while scores in four other subtests were slightly higher in the posttest but statistically less significant. In one of the subtests, which involved constructing a gear using LEGO parts, the scores in the posttest were slightly lower. On average, students scored fewer points for this task in the posttest than in the pretest. However, this change is so slight that it is not considered statistically significant.

This finding is surprising and unexpected, especially considering that one of the crucial units in robotics education, in face-to-face courses, focuses on constructing robotic products from LEGO components. Based on the information provided, several factors could hinder students' ability to build with LEGO parts. Some possible reasons could include a lack of experience with LEGO pieces, which may have made students feel less confident when using and handling them. If students have not had enough opportunities to practice these skills, their performance may improve slowly. Another reason could be the absence of motivation, which is crucial for improvement. If students are not motivated or interested in LEGO, this can affect their performance. In personal interviews, students revealed that more than half of them had hardly played with Lego in their childhood or not at all. It follows - if students had regular opportunities to work, practice, and construct with LEGO parts, they could repeat and refine their skills.

4. Discussion

The results shown in Table 4 indicate that the TechnoMind program contributed to students' practical skills. In the posttests, students in the experimental group performed better in seven out of eight subtests, including working with hydraulics, constructing simple parts, cutting out geometric shapes, dimensioning parts, and screwing nuts. However, they were less successful when working with Lego. Overall, the TechnoMind program has proven beneficial in enhancing students' technical skills in distance education. The results highlight the importance of considering individual factors such as motivation and experience when designing skills development programs. Providing more opportunities for practice and repetition is necessary. It can improve distance education students' technical skills and better prepare them for future careers in technical or engineering fields.

Hypothesis H1 - the TechnoMind program will positively impact the quality of education in the technical subject of robotics - was confirmed. The TechnoMind program was well-designed, and the teachers became skilled in using the program. They explained the curriculum and the individual procedures to the students so that they could proceed according to the program and construct the given robotic product. As a result, the quality of education has been maintained.

During experimental verification, it is necessary to consider its limitations, such as sample size, which may restrict the external validity and generalizability of the results, potentially raising questions about their overall validity. Another significant factor is the selection of students for the experimental and control groups. If the selection process is flawed or certain criteria are not considered properly, it can distort the results and make it difficult to interpret the impact of intervening variables. The Mann-Whitney test used to compare results between experimental and control groups may be influenced by sample size. Additionally, choosing a higher significance level ($\alpha = 0.1$) may increase the risk of a type 1 error, so it's crucial to consider this when evaluating statistical significance.

5. Conclusion

Distance education has posed various challenges and issues in technical education at secondary vocational schools, particularly concerning the improvement of students' psychomotor skills. The results of this work clearly showed that distance education in technical subjects, especially robotics, has limitations and shortcomings. Achieving psychomotor objectives was particularly challenging, especially regarding practical exercises and professional training. Teachers and students encountered a significant drop in motivation and challenges associated with the absence of physical interaction. In conclusion, the proposed TechnoMind distance education program has significantly enhanced students' practical skills. The results also emphasized the importance of personal interaction and support in technical education. Based on these findings, there is a need for further research and the development of innovative approaches to distance education in technical subjects, emphasizing practical exercises and the psychomotor skills development of students.

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