TEM Journal. Volume 13, Issue 4, pages 3405-3412, ISSN 2217-8309, DOI: 10.18421/TEM134-74, November 2024.

Creating a Battery of Subtests to Measure Students' Skills in Technical Education

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Abstract – The study presents the design and creation of skill subtests battery. Before implementing the pedagogical experiment, the skill pretest and relevant subtests (PT1 to PT8) tested the psychomotor skills of students. There were two groups of students - the control group and the experimental group. Each group consisted of 10 students making 20 students overall. As part of the experiment, there was an effort to equalize the control and experimental groups. The results of the Mann-Whitney test showed statistically significant differences in the pretests in four subtests (PT1, PT2, PT3, PT8) between the control and the experimental group. The results of the pretests determine the students' skills before the implementation of the experiment. The experiment deals with the impact of the proposed distance education program on the quality and effectiveness of distance education. It aims to confirm the assumption formulated in hypothesis H1- the program will enhance the quality of teaching robotics, reflected in better skill posttest results. The study emphasizes the importance of technical education. It provides an objective assessment of students' skills and can facilitate planning the educational process.

***Keywords* – Technical education, distance education, construction, skill tests.**

DOI: 10.18421/TEM134-74
https://doi.org/10.18421/TEM134-74

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Received: 02 April 2024.
Revised: 29 August 2024.
Accepted: 02 September 2024.
Published: 27 November 2024.

1. Introduction

Labor markets and employment rates in Slovakia and abroad are more than ever affected by rapid technological progress, such as digital and automated technologies. Focusing on technical education as early as possible, particularly at the elementary level, is significant for facing new challenges and adapting to new professions. Generation alfa is gradually replacing generation z - the generation born when digital technologies were ubiquitous. For this generation, the digital world is a natural part of life, so it tends to be more technologically savvy than previous generations since an early age.

In technical education, students must develop professional knowledge and obtain practical training for future professions. They need to be creative, technically minded, and able to use particular tools and technical equipment. They should master technology and associated programs and apply them in life [1] to face challenges and adapt to new professions. Technical education is one of the main pillars of the future profession. It is necessary to emphasize its advantages. Graduates should be well-prepared for new challenges and life opportunities to develop a positive relationship with technology. Ethical behavior and compliance with ethical codes are of great importance, too. The code of ethics clarifies the behavior expected from an individual in different situations. It makes/helps individuals inculcate the ethical dimensions of their activities [13]. The rapid development of technologies and the increasingly frequent use of intelligent solutions, or the elements of artificial intelligence, require qualified, trained experts. Therefore, the author [2] points out that elementary school students show long-term interest in general fields of education than in technical fields of study. Regarding technical fields, students are most interested in mechanical engineering and electrical engineering. Notwithstanding, the number of students interested in vocational education is insufficient in Slovakia.

According to the author [3], it is inevitable to strengthen manual and technical skills in children and youth already in preschool age. Otherwise, a psychological barrier and reluctance to study technical fields of education could emerge among the young population. They would lose motivation to research, develop, and innovate new things. After graduating high school, students would settle for higher education at any school instead of studying more demanding technical fields, even with the risk of not applying to the labor market.

Therefore, in technical education, it is necessary to develop primarily psychomotor skills in students. These skills are required not only in practical education but mainly when operating machines and working with various devices, tools, or technologies [11]. When teaching technical subjects, psychomotor skills represent a significant factor affecting the achievement of the set goals in this area of education.

In Slovakia, many experts have been researching technical education for a long time [4], [5], [6], [7], [8], [10]. Technical subjects taught through distance education represent several challenges, especially concerning the student's personality development, particularly the conative component. Distance education is limited in terms of implementing technical projects. It affects the support and development of students' skills. Physical supervision and the possibility of immediate feedback, coordination, demonstration, or instruction are also problematic.

Furthermore, access to materials, tools, and technologies was uncertain. Concerning the above, the proposed distance education program for teachers and students aims to alleviate or eliminate the mentioned questions. The program focuses on distance education in robotics, specifically mechanics and drives. It aims to support and develop manual skills. Subsequently, there has been an experiment aimed at monitoring and detailed evaluation of students' skills changes following the program implementation. Among other things, the skill pretests and skill posttests focused on the experimental verification of the distance education program regarding measuring and validating the obtained results.

A skill pretest, measuring skills acquired before experimental verification, was developed. This study presents not only its construction but also the research findings obtained before the implementation of the experiment.

2. Creating a Skill Test

The skill tests assess the students' psychomotor skills. The skill tests are essential for evaluating students' practical abilities and performance in technical education. The skill tests make it possible to assess whether students have the necessary practical skills and abilities. Moreover, they help identify areas where students lack skills and help students gain practice and experience. For students, they represent the motivation to improve practical skills, as students see how their efforts directly influence their results. Skill tests complement the assessment of students and provide a more comprehensive view of their abilities. They can be different and include various technical tasks, from assembling and repairing equipment to programming and engineering activities. The skill tests aim to measure students' practical skills and prepare students for a successful career in technical industries.

The inspiration for creating the skills test was the original proposal of the author [9], who designed a set of test tasks. The tasks focused on assessing the psychomotor skills of students.

The skill test, measuring and evaluating students' practical skills and achievements in real situations, was developed alongside vocational teachers. The test focused on how successfully students managed specific tasks, activities, and procedures relevant to a particular technical field or profession.

The test consists of eight short practical tasks in PT1 -PT8 subtests, which students must complete within the specified time frame. Each task was assigned scores. These tasks deal with drawing and dimensioning simple components, wire forming, cutting, screw operations, and assembling simple parts from "L profiles" and LEGO parts.

A sample presents three of them, focusing on dimensioning a simple component (Figure 1), constructing a square frame (Figure 2), and designing a gear from LEGO parts (Figure 3).

PT1 – subtest COMPONENT DIMENSIONING (time)

Description: the student's task is to dimension the machine component correctly. The test is carried out individually.

Evaluation criteria: during testing, we record the time for the student to correctly measure the dimensions of the machine component using the basic dimensions. We measure time in decimal seconds.

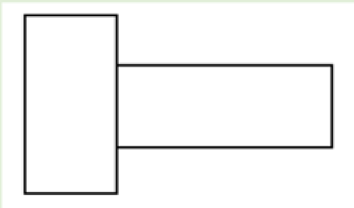
Penalty:

- incorrect dimensioning of the component: + 10s.,

- missing dimensions: +10s.

The wording of the task for the student: Correctly dimension the dimensions of the machine component in the shortest possible time limit.

Machine component:



Correct solution:

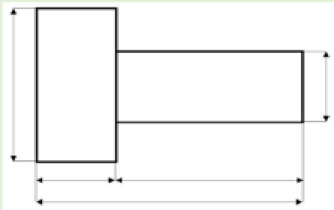


Figure 1. Subtest PT1 component dimensioning

PT6 – subtest SQUARE FRAME CONSTRUCTION (points)

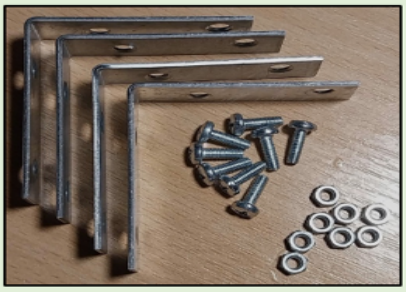
Description: the student receives four "L" shaped metal profiles, the required number of screws with nuts, and a screwdriver. The task for the student is to assemble a solid square frame within a time limit of 3 minutes. The test is carried out individually.

Evaluation criteria: during testing, we record the time for the student to build the square frame. We measure time in decimal seconds. The student is awarded points if the task is completed within the set time limit of 3 minutes and 30 seconds according to the following criteria:
4 points - the frame was constructed within the time limit <= 3 min and is screwed tightly,
3 points - the frame was constructed within the time limit of 3 min 10 s and is screwed tightly,
2 points - the frame was constructed within the time limit of 3 min 20 s and is screwed tightly,
1 point - the frame was constructed within the time limit of 3 min 30 s and is screwed tightly,
0 points - the frame was constructed within the time limit > 3min 30s or not built at all.

Penalty: weak joints: loss of 1 point.

The wording of the task for the student: *Construct a square frame within the shortest possible time (but not over 3 min. 30 s.), using prepared "L"-shaped metal profiles, screws, and nuts, which must be screwed tightly.*

Components:



Correct solution:

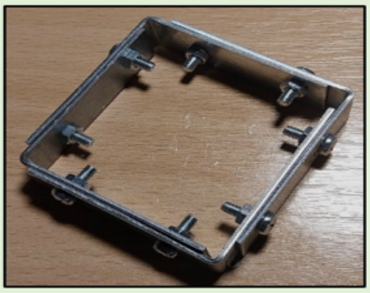


Figure 2. Subtest PT3 square frame construction

PT11 – subtest GEAR CONSTRUCTION (points)

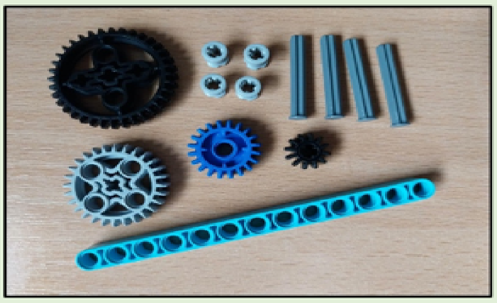
Description: the student receives LEGO parts. The task is to assemble a reduction gear with four stages within a time limit of 1 minute. The test is carried out individually.

Evaluation criteria: during testing, we record the time for the student to assemble a reduction gear with four stages. We measure time in decimal seconds. The student is awarded points if the task is completed within the set time limit of 1 minute and 30 seconds according to the following criteria:
4 points - the gear was constructed within the time limit <= 1 minute and the gear works properly,
3 points - the gear was constructed within the time limit of 1 minute 10 s, the gear works properly,
2 points - the gear was constructed within the time limit of 1 minute 20 s, the gear works properly,
1 point - the gear was constructed within the time limit of 1 minute 30 s, the gear works properly,
0 points - the gear was constructed within the time limit of > 1 min 30 s. or not at all.

Penalty:
- weak joints: loss of 1 point,
- the wheels do not fit together: loss of 1 point,
- the wheels are not sorted correctly by size: loss of 1 point.

The wording of the task for the student: *Construct a reduction gear with four stages from the prepared LEGO parts within the shortest possible time (but not over 1 min. 30 s.).*

Components:



Correct solution:

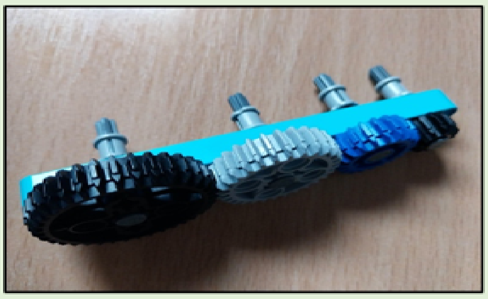


Figure 3. Subtest PT6 gear construction

The subtest PT1 (Figure 1), focusing on dimensioning the component, tests students' technical competence, such as accuracy. Dimensioning is significant in the construction and assembly of products. Correct dimensioning allows assembly teams to accurately and seamlessly assemble products from individual components to achieve accurate, safe, and quality engineering and manufacturing results and to ensure effective communication and collaboration among interested parties.

The subtest PT3 (Figure 2) tests students' fundamental engineering skills, including the precise manipulation of tools and materials. These skills are essential in many industries, such as engineering, construction, and electronics. The skills of accuracy and thoroughness are crucial in constructing a square frame. The student must be able to carry out the construction accurately and correctly. These skills are necessary in various technical and craft fields where minor inaccuracies can lead to errors.

Gears represent a significant part of mechanical systems. The construction and operation of gears are based on movement and power transmission using gears. Subtest PT6 (Figure 3) allows students to understand these principles and get to know them in practice. Gear construction made of LEGO parts affords students to develop their design and engineering skills. The task involves connecting different LEGO parts to create a functional and reliable gear. It helps students understand the principles of mechanics and construction.

The skill test consists of five other subtests. Subtest PT2 determines whether students can assemble a simple hydraulic mechanism using syringes and tubes. Hydraulics is a dominant field in engineering and technology. In this way, students can better visualize the principles of hydraulic systems and the transmission of liquid pressure through hoses and use this principle in various applications, such as lifting mechanisms, brakes, or steering. The subtest PT4 aims to check students' skills when forming wires.

While forming wires, the students are required to have fine motor skills and precise handling of tools. These skills can be practical in many craft activities and the manufacture of precision components. The students' task in subtest PT5 is to construct the front rotating axle of the mechanism from LEGO parts. It can determine the ability of students to create a functional mechanical part. It includes the skill to combine and connect different parts to form a functional mechanism. In this way, students can develop technical skills and the ability to construct. Construction using LEGO parts encourages logical thinking and understanding of mechanical principles. Students need to understand how the different parts work together and to use them correctly to achieve a goal. Students have the opportunity to be creative in constructing and customizing their mechanisms. This task can encourage creativity and innovation in solving technical problems. The subtest PT7 determines the time in which the students can screw the prepared screws into the wood.

This task provides valuable information about the students' practical skills, speed, accuracy, and ability to work with tools. This information can be applicable when choosing a profession and assessing the students' practical skills. The last subtest, PT8, focuses on cutting out specified shapes from paper. The students cut out as many surface areas of the cube as possible within four minutes. The task aims to assess the students' accuracy and speed concerning the performance of tasks requiring fine motor skills. Accuracy and speed play a crucial role in many craft and technical professions, as well as in art and manufacturing. Cutting complex shapes out of paper is significant for artists and craftspeople.

3. Methodology

The proposed battery of subtests intends to verify the skill level of control and experimental group students in pretests before the intervention. The research set consists of an available selection from two groups of students from two classes, one school, one grade, and the same field of study. Each group, the control and the experimental, consisted of 10 students, 20 pupils overall. Descriptive and inferential statistics are used for statistical data evaluation. Results of practical skills tests provide crucial information regarding the level and quality of students' practical skills. Since intervening variables were present during the implementation of the experiment, it is necessary to minimize or eliminate them as much as possible. There was an effort to equalize both groups based on predetermined criteria, such as age, gender, school attendance, time horizon, motivation, teachers, family background, stress level, health status, nationality and culture, and educational results. This fact is verified by testing the compliance of the results between the experimental and control groups.

Figure 4. Implementation of subtest PT1, component dimensioning

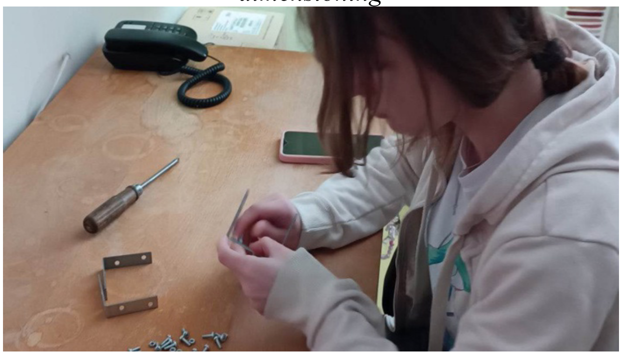


Figure 5. Implementation of subtest PT3, constructing a square frame

Figure 6. Implementation of subtest PT4, wire forming

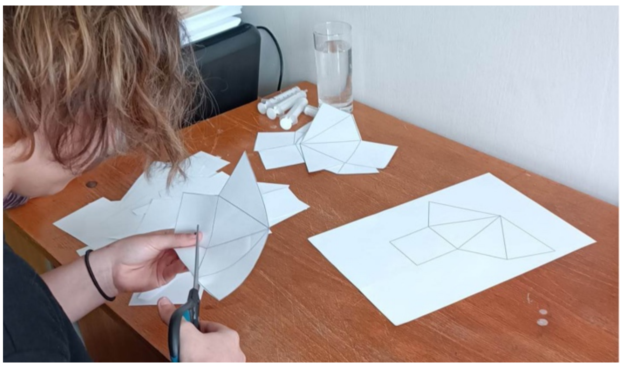


Figure 7. Implementation of subtest PT8, cutting

The non-parametric Mann-Whitney test was used to verify the compliance. The reason for using this non-parametric test was the use of smaller samples [12]. The level of significance was α = 0.1. The reason for this decision is that the sample size is relatively small. A small sample size can increase the risk of a second type of error, meaning the null hypothesis could be accepted even if it is false. Small samples represent a limited amount of data to analyze. It affects the ability of tests to detect actual effects.

Table 1. Results of the Mann-Whitney test when measuring skills in the pretests

PT1	PT2	PT3	PT4
0,024	*0,060*	*0,088*	*0,117*
PT5	PT6	PT7	PT8
0,211	*0,780*	*0,725*	*0,001*

Legend: the PT1 – subtest focuses 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 the construction of a LEGO chassis, the PT6 - subtest focuses on constructing a LEGO gear, the PT7 - subtest focused on screwing, the PT8 - subtest focuses on cutting out.

Table 1 presents the exact p-values for the two-tailed test (Exact Sig., 2-tailed) representing the output of the Mann-Whitney test used within the statistical software platform SPSS. The two-tailed test was used to verify possible differences between the experimental and control groups.

When analyzing the results of the Mann-Whitney test (Table 1) as part of the skills assessment in the pretests, there were observable and statistically significant differences found in four different subtests at the determined level of significance - in the subtest aimed at component dimensioning (marked as the PT1), the subtest aimed at assembling a simple hydraulic mechanism (marked as the PT2), the subtest aimed at constructing a square frame (marked as the PT3), and the subtest aimed at cutting out geometric shapes (marked as the PT8). The graph in Figure 8 compares the average times achieved by students when dealing with individual subtests.

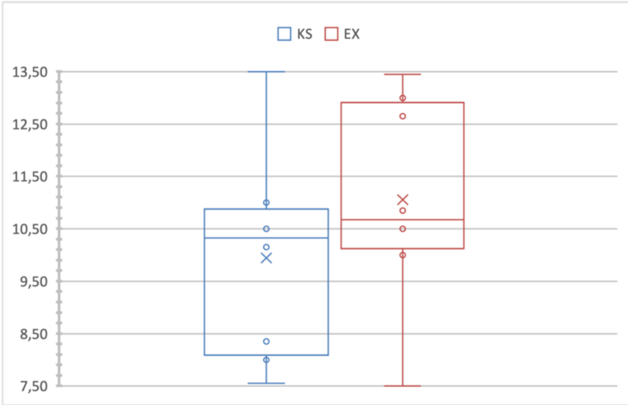


Figure 8. Comparison of the average values of task-solving times between the control and experimental groups

Legend: KS – control group, EX – experimental group, x – average time value

4. Discussion

There was an effort to maintain equality between the control and experimental groups by following thirteen predetermined criteria. According to the Mann-Whitney test, the criterion regarding evaluation has not been met. Students in both groups achieved similar or the same previous assessments and results within the educational process. It helped minimize the impact of the diversity of their skills, abilities, and knowledge. Greater assessment subjectivity by teachers can explain the partial non-fulfillment of this criterion. Teachers tend to evaluate students by their personal opinions, expectations, preferences, and internal prejudices. It affects the objectivity and fair evaluation of the student's achievements. Therefore, the students cannot be assessed based only on the grades awarded.

Other criteria, such as group size, age, gender, school attendance, time frame, available materials and facilities, teachers, motivation, family background, stress level, health status, nationality, and culture, were maintained. The school psychologist, teachers, and class teachers monitored the compliance.

Measuring students' skills through skill tests has many significant advantages and benefits within the educational process. It helps identify the strengths and weaknesses of each student. It accustoms the educational process to students' needs. Moreover, feedback is very significant. It facilitates the planning of remedial measures and monitors the student's progress. At the same time, the skill tests helped to reveal three students with above-average skills, with whom the teachers will continue to work individually. Interviews with students confirmed that solving individual tasks was a motivation for improving skills.

Skill tests enable an objective and fair assessment of students' achievements. Moreover, the skill tests facilitate planning lessons and adapting the educational process to the student's needs and levels. They help students understand their strengths and interests better. It can affect the choice of a field of study at university or a future profession. Skill tests also improve students' self-confidence, critical thinking, and problem-solving. They help identify students with special educational needs in due time and adapt educational processes to meet their needs. Progress in students' skills contributes to development and the quality of life in society. These tests also contribute to the assessment of the effectiveness of the educational system.

5. Conclusion

Psychomotor skills play a crucial role in everyday life. The need to develop these skills is essential for education and personality formation. Acquiring work skills depends on mechanical exercise, intellect, and motivation. Skill tests are fundamental to technical education. Skills such as handling the parts, assembly, and disassembly work, using hand tools or power devices effectively, or reading technical drawings are assessed through skill tests. They provide a comprehensive picture of students' practical abilities and help identify areas for improvement.

As presented in this paper, the creation and application of skill tests allow for assessing and developing students' practical skills. The tests contain a variety of tasks that simulate real-world technical problems and provide students with opportunities to gain practical experience and skills relevant to future careers. Skill tests provide a comprehensive picture of students' practical abilities, complementing the theoretical and written assessment. Skill tests motivate students to improve practical skills, and students can see the results of their efforts directly. They help identify the strengths and weaknesses of individual students. It allows adaptation of teaching to the needs of individual students. The tests provide an objective and fair assessment of students' achievements. The students gain practice and valuable experience.

A small research sample of students is considered a disadvantage of testing. It can place a limit on the generalizability of the results. Moreover, the teachers may assess the skills subjectively. Therefore, when testing, more experts are needed to eliminate such subjectivity. The intervening variables may influence the results despite the efforts to minimize them.

In the future, it is necessary to work with a larger sample size and monitor the development of students' practical skills from a longer-term perspective. There is a need to apply skill tests in different technical areas to see if results are consistent across individual disciplines. It is required to develop methodologies and tools to minimize the subjectivity of evaluation, such as automated evaluation systems. Research should focus on the impact of various intervention programs, such as additional courses or practical workshops, aiming to improve students' practical skills.

Measuring and developing psychomotor skills is critical to success in technical fields. Skills tests provide valuable information for teaching and education. They make it possible to improve students' practical abilities and skills.

Acknowledgements

The contribution is a partial output of grant task VEGA No. 1/0550/22 Current state, trends, and problems in technical education at the lower and upper secondary education level concerning distance education (2022 - 2024).

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