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Some results of research on the development of students' technical thinking

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Abstract

The development of modern science and technology is directly related to the level of technical skills and technical thinking that enable people to perceive the real world, apply it to their daily lives, and design various tools and technologies starting from simple instruments. Considering global development trends, Mongolia's national development policy, and the current situation of the "Design and Technology" subject in secondary schools, it is important to study the level of students' technical thinking in general education and to identify effective methodologies for its development.

Keywords

technical thinking; technical creativity; robotics; design and technology education; mechanics and electronics

1. Introduction

The development of modern science and technology is directly related to the level of technical skills and technical thinking that have enabled people to perceive the real world, apply it to their daily lives, and design a wide range of tools and technologies, starting from simple instruments. In the era of rapid innovation, technological advancement, smart technologies, and artificial intelligence, many countries consider the study and development of students' technical thinking as a vital contribution to future progress.

For instance, according to the study conducted by the OECD's National Experts on Science and Technology Indicators (NESTI), it has been emphasized that "the feature of this century will not be merely the perception of reality, but rather the 'century of thinking,' in which individuals learn and create knowledge based on their own potential" (OECD, Frascati Manual, 2015). This reflects a globally recognized perspective.

Taking into account global development trends, Mongolia's national development policy, and the current situation of the “Design and Technology” subject in general education schools, it is essential to study the level of technical thinking of upper secondary school students and to define methodologies for its development.

2. Technical Thinking

Through thinking, human beings are able to perceive and understand real phenomena creatively, transform them, and generate outcomes or abilities that previously did not exist in a given context. Therefore, it is essential to foster such abilities and modes of thinking through well-organized activities and instruction. The distinctive feature of thinking lies in its capacity to create the necessary conditions for problem-solving in any situation, to focus deeply on the objectives to be achieved, to creatively transform given conditions, and to approach problems from multiple perspectives, requiring a set of complex competencies.

One of the most common tools for studying human cognition is the use of tests. This method is considered a fundamental approach in psychological diagnostics, as it provides an opportunity to investigate cognitive processes and abilities through structured responses to pre-designed questions or the performance of specific exercises and tasks. The use of tests to measure intellectual activity and cognitive abilities is believed to have originated as early as 1869.

During the period 2016–2019, Mongolia undertook a comprehensive revision of its curricula at all levels of education, guided by the aforementioned approaches. Within this framework, the “Design and Technology” curriculum in general secondary education was revised to include a newly developed “Mechanics and Electronics” module. The content was structured progressively and in greater depth, providing students with opportunities to work in digital technological environments, manage smart technologies, and learn programming. This revision laid a solid foundation for the development of students’ technical thinking skills.

Based on the senior secondary curriculum, textbooks, teacher manuals, and learning guidelines, we independently developed 70 tasks within the “Mechanics and Electronics” module, using Bennett’s test as a reference framework. These 70 tasks were subsequently analyzed according to the five components of technical thinking proposed by researcher M.V. Mukhina: comprehension, visualization, practice, technical language, and cognitive speed.

The test for assessing students’ technical thinking was designed based on the five components of technical thinking, while maintaining the essential characteristics of Bennett’s test. During the development of the revised test, the knowledge, skills, and attitudes outlined in the “Mechanics and Electronics” module of the general secondary education Design and Technology curriculum were aligned with the five components of technical thinking.

The appropriateness of the developed test, which comprised 70 tasks, was verified. The instructional intervention aimed at developing students’ technical thinking was conducted by dividing participants into two groups: a control group of 30 students and an experimental group of 30 students. The teaching utilized a set of instructional materials designed to enhance technical thinking, specifically the revised kit titled "Technical Automated Projects".

The outcomes of the instructional intervention were evaluated using the 70-task test developed based on Bennett's test framework. The results were analyzed and compared between the two groups to determine the effectiveness of the intervention.

The relationship between the 70 tasks completed by students in the control and experimental groups and the components of technical thinking was presented in a table.

Table 1. Distribution of the components of technical thinking across the 70 tasks

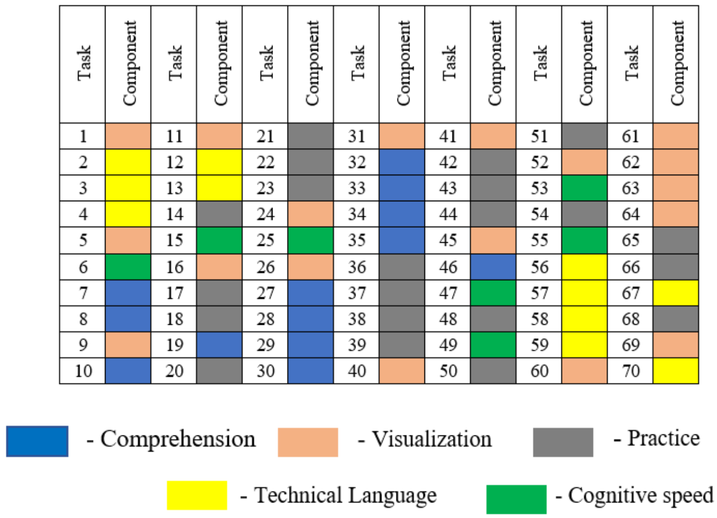
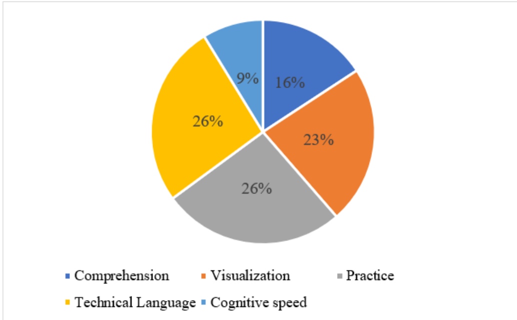


Table 1. Distribution of the components of technical thinking within the assessment test

Component (Technical Thinking)	Number of Tasks
Comprehension	13
Visualization	18
Practice / Practical Skills	21
Technical Language	11
Cognitive Speed	7

Figure 2. Contribution of Technical Thinking Components across 70 Tasks



If we analyze the test assignments according to the components of technical thinking, out of a total of 70 tasks, 16% involve content at the level of understanding, 26% involve representational content, 26% are practically oriented tasks, 16% involve technical language, and 9% are tasks that assess cognitive speed.

Table 3. Reliability Statistics

Reliability Statistics

Cronbach's Alpha	N of Items
.810	70

The table above illustrates the internal consistency of the 70 tasks we developed. A Cronbach's alpha coefficient of 0.7 or higher is considered to indicate good internal consistency among the tasks. The internal consistency of our developed test, with a coefficient of 0.810, confirms its reliability. This demonstrates that the test can effectively assess the development of students' technical thinking.

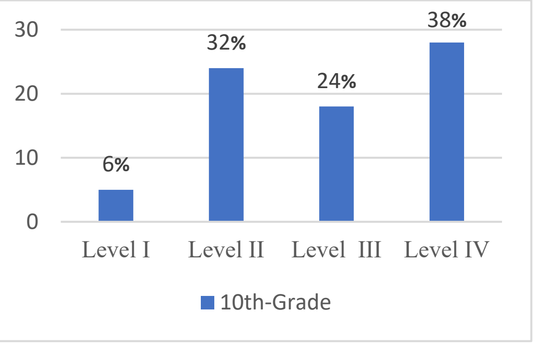
3. Experimental Study

The instructional program was implemented in Design Technology classes for 10th-grade students at three targeted schools, with a total of 75 students participating. The level of students' technical thinking development was assessed using newly developed criteria based on the results of the experimental study.

Table 4. Indicators of Technical Thinking Levels of 10th-Grade Students

Level	I	II	III	IV
Number of Students 75	5	24	18	28
Percentage	6%	32%	24%	38%

Figure 2. Indicators of Technical Thinking Levels of 10th-Grade Students



4. Conclusion

- Among the 75 10th-grade students who participated in the study, 6% were at Level I, indicating insufficient technical "understanding," as they were unable to grasp the working principles of technical moving constructions or represent their characteristics graphically. Thirty-two percent met the criteria for Level II, demonstrating the ability to understand the structure, working principles, and patterns of technical moving constructions, to model them abstractly, and to explain their own creations.
- Some students occasionally misread assembly sequences, circuit diagrams, and working drawings of technical moving constructions, indicating a need to improve their "visualization" thinking. At Level III, 24% of the students conducted objective analyses of technical moving constructions, thought systematically, understood the working principles and structure of their creations well, and showed good manual skills, reflecting sufficiently developed "practical" thinking.
- Thirty-eight percent of the students reached Level IV. This indicates that they were able to anticipate the final outcome of technical moving constructions, integrate and evaluate visual information, and make informed judgments. They were capable of fully assembling technical moving constructions, successfully conducting experiments, proposing improvements, and further developing their creations, demonstrating fully developed "cognitive agility."

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