

RESEARCH ARTICLE

Stages and Structural Components of Developing Students' Technological Thinking

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Abstract

The article analyzes the main stages and structural components of developing students' technological thinking. The development stages include acquiring knowledge, forming practical skills, generating creative solutions, and making independent decisions. The structural components are identified as knowledge, skills, competencies, and information technology literacy. The findings provide guidance for effectively fostering technological thinking within the educational process.

KEY WORDS

Technological thinking, student, development stages, structural components, innovative education.

INTRODUCTION

In the 21st century, societal development is closely intertwined with digital innovations, artificial intelligence, and advanced technologies. Within the higher education system, fostering students' technological thinking has become a strategic priority. The STEM (Science, Technology, Engineering, Mathematics) education model is considered an effective means for developing technological thinking, as it integrates theoretical knowledge with practical application.

Experience from developed countries demonstrates that methods such as Project-Based Learning, Problem-Based Learning, and Design Thinking significantly enhance the development of systematic and technological thinking in students. The findings of this study contribute to the creation of a conceptual model for technological thinking, the integration of innovative methods into the educational process, and the improvement of students' professional preparedness.

The ultimate goal of students' professional formation focuses on the following aspects:

- Professional training is primarily shaped by the tools of the academic discipline, the content of pedagogical activities, and the individual capabilities of the student;
- Students achieve personal initiative by acquiring a holistic understanding of the content and objectives of design and technological activities, as well as potential challenges and problems that may arise during these processes.
- Preparing future engineers from a technological perspective has a clear objective: to focus on the structure and content of both general and specialized knowledge as it relates to the technical and technological specifics of industrial enterprises.
- The expected and achievable outcomes of students' professional activities are determined by multiple factors, including the student's personal characteristics, orientation (needs, interests, value system, work, mindset, motivations), level of knowledge (knowledge, skills, competencies, and the continuous pursuit of learning), upbringing (moral, aesthetic,

physical, and labor-related development), and cultural literacy (ability to accept social and cultural values, intellectual, economic, ecological awareness, as well as cognitive and physical work ethics, attitudes, and behavior).

According to educational scientist N.A. Muslimov, "competence is defined by the application of the knowledge, skills, and abilities required for professional activity in a manner that is personally and socially meaningful." Based on this understanding, foreign scholars such as A.A. Verbitsky, O.G. Larionova, D. Raven, N. Chomsky, A.V. Khutorsky, Y.G. Tatur, and others have used these concepts as a foundation for their scientific research.

The study is theoretical and conceptual in nature. The following methods were employed:

1. Content analysis of scientific literature;
2. Comparison and generalization;
3. Modeling based on a systematic approach;
4. Analysis of pedagogical practices.

The methodological foundation of the study is based on a systematic approach, a competency-based approach, and the learner-centered education concept.

Systematic Approach:

1. Principle of integrity – all components of technological thinking (cognitive, operational, analytical-reflective, creative) develop in an interconnected manner.
2. Structurality – thinking possesses an internal structure, with each component performing a specific function.
3. Hierarchy – development occurs gradually in sequential stages.
4. Integrativity – integration of theoretical knowledge with practical activity is ensured.

Competency-Based Approach: The competency-based approach is one of the main directions in modern educational paradigms, emphasizing the ability to apply knowledge in practical contexts. This approach ensures:

- integration of knowledge, skills, and competencies;
- education oriented toward real-life situations;

- development of independent decision-making skills;
- promotion of innovative and critical thinking.

Within this framework, methods such as Project-Based Learning, Problem-Based Learning, and case-study techniques serve as effective tools. As a result, students not only understand technological processes but also learn to apply them in practice.

Learner-Centered Education Concept: In the process of developing technological thinking, a learner-centered approach provides the following opportunities:

- defining an individual learning trajectory;
- fostering creative and independent thinking;
- promoting reflective activity;
- enhancing intrinsic motivation.

Integration of Approaches: The systematic, competency-based, and learner-centered approaches are harmoniously combined to form a methodological model for developing technological thinking:

- Systematic approach – defines the structure;
- Competency-based approach – ensures effectiveness;
- Learner-centered approach – guarantees individualization.

Characteristics of Technological Thinking:

1. Systematicity – the ability to perceive objects and processes as integrated systems;
2. Algorithmic thinking – solving problems step by step;
3. Optimization orientation – improving efficiency in processes;
4. Innovativeness – generating new solutions.

The structural composition of competence has been thoroughly examined by scholars such as V.A. Adolf, I.D. Belonovskaya, I.A. Zimnaya, S.I. Osipova, V.I. Teslenko, and others.

V.A. Adolf and I.S. Volegzhana proposed a structural-level model of competence, which includes motivational, goal-oriented, and content-operational components. This model reflects an individual's system of motivational forces, specific needs and demands, life plans, and proposals, as well as their subjective social and professional capabilities.

According to I.A. Zimnaya, competence consists of cognitive, motivational-value, and emotional-volitional components.

Research dedicated to technological thinking suggests that technological thinking represents an integral characteristic

formed during the acquisition of knowledge, skills, and competencies (KSCs) used in professional activities. It reflects an individual's ability to receive, analyze, create, store, and transmit information using new innovative technologies and technical tools.

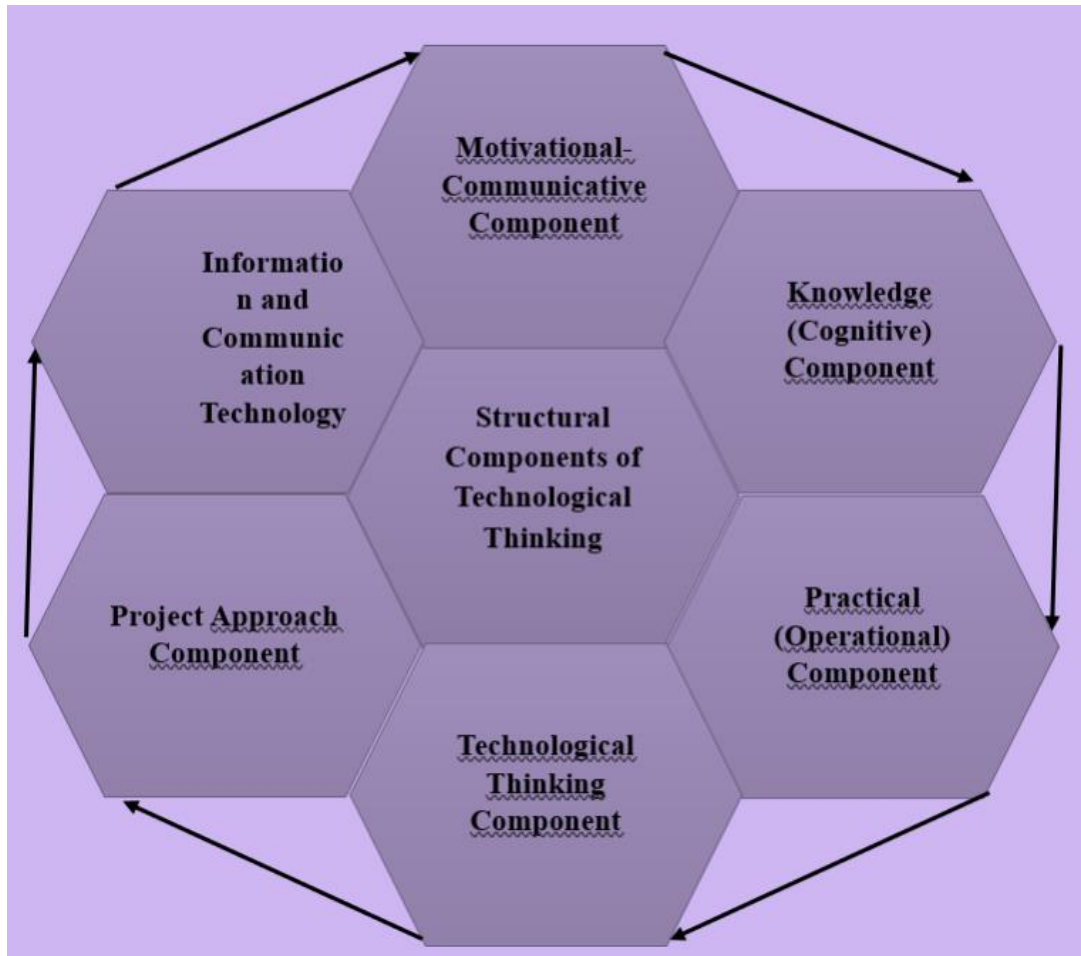


Figure 1.1. Structural Components of Technological Thinking

Below are general definitions of the structural components of technological thinking:

1. **Motivational-Communicative Component** – In developing the technological thinking of civil engineering students, their intrinsic interest in the profession, the drive for independent decision-making, and communication skills play a crucial role.
2. **Knowledge (Cognitive) Component** – This component forms the necessary theoretical knowledge system related to the construction field. Students acquire solid knowledge based on subjects such as construction materials, structures, building design, construction physics, statics, mechanics, geodesy, and regulatory documents (e.g., SNIP, GOST). They

develop technological thinking by integrating interdisciplinary knowledge aimed at understanding real construction processes.

3. **Practical (Operational) Component** – This component enables students to apply the acquired theoretical knowledge in practical settings.
4. **Technological Thinking Component** – This component guides students to analyze real problems in construction and develop alternative solutions based on critical thinking.
5. **Project Approach Component** – Innovative thinking plays an important role in modern construction processes. This component introduces students to advanced technologies such as 3D construction technology, “green” buildings, BIM

modeling, energy-efficient solutions, and smart buildings managed by intelligent devices.

6. Information and Communication Technology (ICT) Component – Effective use of ICT in construction is an indispensable skill for a modern engineer.

In modern education systems, the development of students' practical knowledge and skills, as well as their ability for independent thinking, problem-solving, and innovative

activity, plays a vital role. This competency is developed gradually through sequential stages. Each stage has its own objectives, content, and methods aimed at shaping students into independent thinkers, problem solvers, and technological thinkers.

The stages of developing technological thinking are illustrated in Figure 1.2.

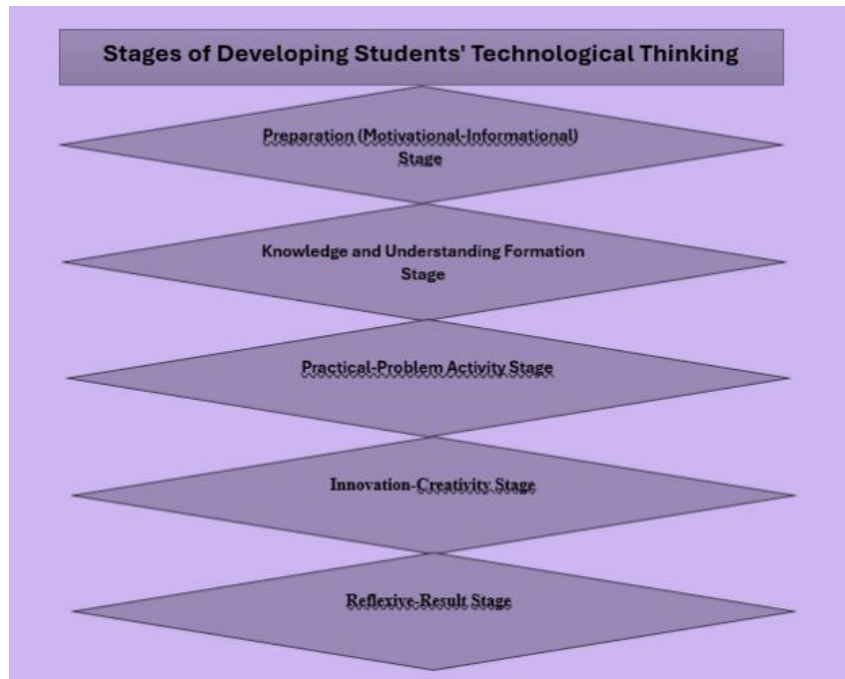


Figure 1.2. Stages of Developing Students' Technological Thinking

1. Preparation (Motivational-Informational) Stage – Formation of the aspiration toward technological thinking. This stage awakens the students' initial interest in technological thinking and introduces them to the essence of technological processes and the professional content of the field.

2. Knowledge and Understanding Formation Stage – Systematic assimilation of theoretical foundations. This stage aims to develop students' fundamental knowledge and scientific concepts related to the basics of technological thinking. Students begin to comprehend the logic of technological process competencies, the constructive structure, and the interconnection between technological systems, while mastering regulatory documents in construction, physical-mathematical foundations, and modeling principles.

3. Practical-Problem Activity Stage – Interactive engagement with technological processes. At this stage,

students develop skills to perceive technological processes independently and apply them in practice through active involvement.

4. Innovation-Creativity Stage – Development of creative and advanced approaches. This stage serves to cultivate students' technological thinking at a high level, fostering independence, creativity, and innovation.

5. Reflexive-Result Stage – Analysis, evaluation, and self-improvement. This stage involves assessing the level of technological thinking development, final evaluation, and guiding students toward continuous self-development.

Overall, the research results demonstrate that developing technological thinking based on systematic, competency-based, and student-centered approaches enhances the effectiveness of higher education. The proposed model serves as both a theoretical and practical foundation for

strengthening students' professional readiness, adapting them to modern technological environments, and preparing them for innovative activities.

It is important to emphasize in the discussion that technological thinking is not limited to theoretical knowledge alone. The analytical-reflexive and creative components enable students to make independent decisions, optimize technological processes, and develop innovative solutions.

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