HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

DEVELOPING TECHNICAL THINKING COMPETENCE IN FUTURE TEACHERS THROUGH PROJECT-BASED LEARNING

Ibragimov Muslimbek Erkinjon ugli
Namangan State University
Lecturer, Department of Digital Education
muslimbek.mb9403@mail.ru
ORCID:0009-0008-8294-6196
Doi: https://doi.org/10.5281/zenodo.21929317

Abstract: This article examines the development of technical thinking competence in future teachers through project-based learning. Technical thinking competence is interpreted as an integrated professional ability that includes analysis of technical problems, modeling of solutions, practical implementation, testing, and reflective justification of decisions in educational contexts. The article argues that this competence is especially important for teacher education because modern pedagogy increasingly requires technology integration, interdisciplinary STEM tasks, and the ability to organize practical inquiry. Based on a conceptual synthesis of literature on competence-based education, project-based learning, teacher preparation, and technology education, the article proposes methodological conditions for organizing project work in higher education. These conditions include professionally oriented tasks, interdisciplinary content, collaboration, formative feedback, access to digital and material resources, and criterion-based assessment. The article also presents stages of project-based learning and criteria for assessing technical thinking competence. Recommendations are offered for improving future teacher training through systematic project modules, reflective documentation, and pedagogically meaningful technical design tasks.

Keywords: technical thinking competence; future teachers; project-based learning; teacher education; STEM education; competence-based education; technology integration.

INTRODUCTION. Teacher education is increasingly expected to prepare graduates who can work not only with subject content, but also with technological systems, digital tools, engineering ideas, and practical problem-solving situations. In this context, technical thinking competence becomes an important professional quality of future teachers. It enables a teacher to understand the structure and function of technical objects, explain cause-and-effect relations in technological processes, model alternative solutions, and guide learners through practical inquiry. For teachers of science, information technology, technology education, and interdisciplinary STEM subjects, this competence is directly connected with instructional quality, classroom innovation, and students' readiness for real-world problem solving.

Technical thinking competence can be defined as an integrated ability to analyze technical problems, identify functional relations, use scientific and technological knowledge, design and test solutions, and justify decisions on the basis of efficiency, reliability, safety, and educational value. It includes cognitive, operational, creative, reflective, and communicative components. Unlike isolated technical knowledge, competence is expressed in action: a future teacher demonstrates it when planning a technology-rich lesson, designing a small prototype or digital model, troubleshooting an instructional device, or helping students transform an abstract idea into a feasible project outcome.

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Traditional lecture-based training is insufficient for the systematic development of this competence because technical thinking requires activity, experimentation, design decisions, and reflection. Project-based learning (PBL) responds to these requirements by organizing learning around meaningful problems and tangible products. In PBL, students formulate a problem, plan work, search for information, model solutions, create a product, test results, and present evidence-based conclusions. Such learning conditions closely correspond to the logic of technical thinking and to the professional tasks future teachers will face in modern educational environments.

The relevance of this issue is strengthened by rapid digitalization and the expansion of STEM-oriented learning tasks in general and higher education. Future teachers are expected to interpret technical information, select appropriate tools, and design learning activities that connect scientific concepts with practical applications. When they lack technical thinking, technology may be used superficially, as decoration rather than as a means of inquiry. Therefore, teacher education should intentionally cultivate habits of analysis, design, experimentation, and evidence-based explanation.

The aim of this article is to clarify how project-based learning can be used to develop technical thinking competence in future teachers and to outline methodological conditions, implementation stages, assessment criteria, and practical recommendations for teacher education programs. The article is conceptual and methodological in nature, synthesizing relevant literature on competence-based education, teacher training, project-based learning, STEM education, and technological thinking.

LITERATURE REVIEW. The theoretical foundation of PBL is closely related to constructivist and experiential views of learning. Dewey (1938) argued that meaningful education should be connected with experience, inquiry, and reflective action. Kilpatrick (1918) later described the project method as purposeful activity in which learners solve problems that have personal and social significance. Contemporary studies have expanded these ideas and show that PBL can support deep understanding, motivation, collaboration, and transferable problem-solving skills when it is carefully structured (Blumenfeld et al., 1991; Thomas, 2000).

Research on teacher education emphasizes that future teachers need opportunities to connect pedagogical theory with practical design. Shulman (1986) introduced the idea of pedagogical content knowledge, showing that effective teaching requires the transformation of subject knowledge into teachable forms. In technology-rich education, this principle is extended by the need to integrate technological, pedagogical, and content knowledge (Mishra & Koehler, 2006). Therefore, the development of technical thinking competence should not be separated from didactic planning, classroom management, assessment, and reflection on learners' needs.

Competence-based education focuses on observable abilities that combine knowledge, skills, values, and attitudes in professional contexts. In teacher preparation, competence is not limited to knowing educational concepts; it includes the capacity to apply them in authentic pedagogical situations. Tondeur et al. (2017) note that preparing teachers for technology integration requires modeling, collaboration, reflection, and authentic tasks. These principles are also relevant to technical thinking because students must repeatedly experience the logic of design, analysis, and improvement rather than only memorize technical terminology.

The literature on STEM and technology education also supports the importance of technical and design thinking. Technological literacy involves understanding the nature of technology, the relationship between technology and society, and the processes by which technological solutions are created (de Vries, 2005; Ropohl, 1997). Engineering and STEM education research highlights modeling, systems thinking, optimization, and evidence-based iteration as central learning processes (English, 2016). These processes are compatible with PBL because projects require students to move from a problem situation to a designed and justified solution.

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For future teachers, technical thinking should be understood as both a cognitive and methodological resource. Cognitively, it supports the interpretation of systems, functions, processes, algorithms, and cause-and-effect relations. Methodologically, it helps the teacher transform technical content into accessible learning tasks, demonstrations, questions, and assessment activities. This dual nature explains why project tasks in teacher education should end with a pedagogical product or teaching scenario, not only with a technical artifact.

At the same time, PBL does not automatically produce high-quality learning outcomes. Studies show that successful PBL requires clear goals, scaffolding, access to resources, formative assessment, collaboration norms, and opportunities for reflection (Barron & Darling-Hammond, 2008; Hmelo-Silver, 2004). For future teachers, PBL must also include pedagogical reflection: students should analyze not only whether their technical product works, but also how the project could be taught, adapted, assessed, and managed in school or university settings.

METHODOLOGY. This article uses a conceptual-methodological research approach. The main method is analytical synthesis of academic literature on PBL, competence-based teacher education, technology integration, STEM education, and technological thinking. On this basis, a methodological model is proposed for developing technical thinking competence through project-based learning in teacher education programs. The model is intended for use in courses related to information technology, educational technologies, technology education, science teaching methods, and interdisciplinary pedagogical practice.

The proposed methodology is based on four principles. First, learning tasks should be professionally oriented; projects must be connected with future teaching practice, such as creating a digital learning resource, designing a laboratory demonstration, developing a simple educational device, or preparing a STEM lesson project. Second, projects should include a technical problem that requires analysis, modeling, construction, testing, or optimization. Third, students should work through structured stages that gradually develop independence. Fourth, assessment should measure both the product and the thinking process, including problem analysis, design logic, technical justification, collaboration, and reflection.

Methodological conditions for developing technical thinking competence include an interdisciplinary content base, access to digital and material resources, systematic use of design tasks, collaborative learning, formative feedback, and reflection. The teacher educator's role is to create a problem situation, explain requirements, provide scaffolds, monitor progress, organize peer review, and guide students in connecting technical decisions with pedagogical implications. Student activity should include inquiry, planning, modeling, prototyping, testing, documentation, presentation, and self-assessment.

Project tasks may vary in complexity according to the year of study and students' initial preparation. At an introductory level, students may analyze the structure of a simple device, design a digital poster explaining a technological process, or prepare a short algorithmic task. At a higher level, they may develop an interactive simulation, a microcontroller-based teaching aid, a virtual laboratory instruction, or an interdisciplinary STEM project plan. The essential requirement is that every project contains a problem, a design decision, a product, and a reflective pedagogical justification.

The PBL process can be organized in six interrelated stages: problem orientation, analysis and planning, design and modeling, implementation, testing and improvement, and presentation with reflection. These stages are flexible; students may return to earlier stages when testing reveals weaknesses. Such iteration is essential because technical thinking develops through comparison of alternatives and correction of errors. Table 1 summarizes the stages of developing technical thinking competence through project-based learning.

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Table-1. Stages of Developing Technical Thinking Competence through Project-Based Learning

Stage	Teacher Activity	Student Activity	Expected Result
Problem orientation	Presents an authentic pedagogical-technical problem, explains goals, criteria, and constraints.	Identifies the problem, asks questions, clarifies learning and technical requirements.	Initial problem understanding and motivation for inquiry.
Analysis and planning	Guides information search, helps define resources, timelines, and team roles.	Analyzes causes, studies examples, formulates a plan, distributes responsibilities.	Structured project plan and justified work strategy.
Design and modeling	Provides scaffolds for diagrams, algorithms, prototypes, and lesson design links.	Creates sketches, digital models, algorithms, or design alternatives.	Technical model connected with educational purpose.
Implementation	Monitors progress, gives formative feedback, ensures safe and effective tool use.	Develops the product, prepares materials, documents decisions and difficulties.	Working prototype, digital resource, or project product.
Testing and improvement	Organizes peer review, testing procedures, and discussion of errors.	Tests the product, compares results with criteria, improves the solution.	Optimized solution and evidence-based correction.
Presentation and reflection	Facilitates defense, evaluation, and pedagogical reflection.	Presents the result, explains technical logic, evaluates teaching applicability.	Demonstrated competence and transferable teaching recommendations.

RESULTS AND DISCUSSION. The synthesis indicates that PBL can contribute to technical thinking competence because it creates a learning environment in which future teachers must apply knowledge to practical and pedagogical problems. During problem orientation, students learn to see a technical issue as a structured task rather than a vague difficulty. In the planning stage, they identify functional requirements, resources, constraints, and expected outcomes. During modeling and implementation, they transform ideas into diagrams, algorithms, digital prototypes, physical models, or instructional materials. Testing and improvement strengthen analytical thinking because students compare expected and actual results and justify modifications.

For teacher education, the most important result of PBL is the integration of technical and pedagogical reasoning. A student who develops a digital simulation, for example, must understand not only the software tool but also the learning objective, age characteristics of learners, classroom time, assessment method, and possible misconceptions. In this way, technical thinking becomes part of professional pedagogical competence. Future teachers learn to select technologies rationally, explain technical processes clearly, and organize student-centered project work in their own future classrooms.

The implementation of PBL also changes the role of the teacher educator. Instead of providing ready-made instructions for every action, the instructor creates a controlled space for independent

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decision-making. This does not mean leaving students without support. Scaffolding should be provided through guiding questions, checklists, examples of project documentation, interim consultations, and clear rubrics. Such support helps students remain responsible for technical choices while preventing project work from becoming chaotic or purely intuitive.

Another significant outcome is the development of reflective independence. Technical thinking is strengthened when students evaluate why a particular solution was selected, what limitations it has, and how it can be improved. Reflection also helps students understand that technical solutions are not neutral; they involve safety, cost, accessibility, sustainability, and educational relevance. Therefore, PBL should include written project logs, peer feedback, oral defense, and individual reflection reports.

Assessment of technical thinking competence should be criterion-based and transparent. The assessment system should include diagnostic, formative, and summative components. Diagnostic assessment identifies students' initial ability to analyze technical problems and use technological concepts. Formative assessment supports progress during project work through feedback on plans, models, prototypes, and team interaction. Summative assessment evaluates the final product, documentation, presentation, and reflective explanation. Table 2 presents concise criteria that may be adapted for teacher education courses.

The criteria show that technical thinking competence cannot be measured only by the correctness of a final product. A technically simple project may demonstrate strong competence if the student clearly analyzes the problem, justifies design decisions, tests the solution, and explains educational use. Conversely, an attractive product may reveal weak competence if it lacks technical logic, evidence, or pedagogical suitability. For this reason, rubrics should balance cognitive, practical, creative, collaborative, and reflective indicators.

The proposed approach also has institutional implications. Teacher education programs should provide project-oriented modules, interdisciplinary cooperation between pedagogy and technology-related departments, access to makerspace or digital laboratory resources, and partnerships with schools. Instructors need professional development in PBL facilitation and assessment. Curriculum designers should avoid treating technical tasks as isolated practical exercises; instead, projects should be aligned with learning outcomes, pedagogical practice, and research assignments.

Several recommendations follow from this discussion. First, project topics should be selected according to real educational needs, such as explaining a difficult concept, improving a laboratory demonstration, or supporting inclusive access to learning materials. Second, every project should require students to document the relationship between technical decisions and pedagogical outcomes. Third, peer review should be used as a regular mechanism for evaluating feasibility, clarity, and instructional value. Fourth, assessment should include individual accountability so that collaborative projects reveal each student's contribution to analysis, design, testing, and reflection.

Table-2.Criteria for Assessing Technical Thinking Competence

Criterion	Indicator	Assessment Level
Problem analysis	Identifies technical problem, constraints, causes, and expected functions.	Low: fragmented; Medium: partially justified; High: systematic and evidence-based.
Technical knowledge application	Uses concepts, tools, algorithms, or technological principles correctly.	Low: inaccurate; Medium: generally correct; High: precise and transferable.
Design and	Creates diagrams, models, prototypes,	Low: incomplete; Medium:

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Criterion	Indicator	Assessment Level
modeling	or plans aligned with project goals.	functional; High: coherent, feasible, and optimized.
Practical implementation	Develops and tests a product, resource, or solution using appropriate methods.	Low: weak execution; Medium: usable result; High: reliable and well documented.
Creativity and optimization	Proposes alternatives, improves design, and adapts to constraints.	Low: reproductive; Medium: some adaptation; High: innovative and justified.
Pedagogical integration	Explains how the technical solution supports teaching and learning.	Low: unclear; Medium: relevant; High: methodologically strong and learner-centered.
Reflection and communication	Defends decisions, evaluates limitations, and presents results clearly.	Low: descriptive; Medium: partly analytical; High: critical and evidence-based.

CONCLUSION. Technical thinking competence is a relevant component of future teachers' professional preparation because modern education increasingly relies on technological tools, interdisciplinary problem solving, and the ability to guide learners through practical inquiry. This competence includes the ability to analyze technical situations, model and implement solutions, evaluate results, and explain technological processes in pedagogically meaningful ways.

Project-based learning is an effective methodological approach for developing this competence because it combines problem orientation, design activity, collaboration, experimentation, and reflection. Its effectiveness depends on clear methodological conditions: authentic professional tasks, interdisciplinary content, structured stages, adequate resources, formative feedback, and criterion-based assessment. In teacher education, PBL should be organized not only to create technical products but also to develop pedagogical reasoning about how such projects can be used in learning environments.

The proposed model is particularly valuable because it links the formation of technical thinking with future professional action. A technically competent future teacher should be able to design, explain, evaluate, and adapt technological solutions for educational purposes. Therefore, project-based learning should be treated as a regular methodological strategy rather than an occasional creative assignment.

Future teacher training can be improved by integrating project modules into methodology courses, using rubrics for technical thinking competence, encouraging reflective project documentation, strengthening cooperation with STEM and technology specialists, and creating conditions for students to test project products in educational practice. Further empirical research should examine the effectiveness of the proposed model through experimental studies with pre-service teachers in different subject areas.

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