A METHODOLOGICAL APPROACH TO DEVELOPING STUDENTS' TECHNICAL CREATIVITY THROUGH PROJECT-DESIGN TASKS AND DIGITAL PROTOTYPING

Madaminova Mavjuda Erkinovna
Farg'ona davlat universiteti, mustaqil tadqiqotchi
mavjudamadaminova1985@gmail.com
ORSID ID 0009-0004-2160-1945

DOI: https://doi.org/10.5281/zenodo.21256197

Abstract. This thesis presents a methodological approach to developing students' technical creativity through the integration of project-design tasks, digital prototyping, and formative assessment. The proposed model combines problem framing, idea generation, prototyping, testing, and reflection within a single instructional cycle and strengthens independent thinking and engineering decision-making.

Keywords: *technical creativity, project-design tasks, digital prototyping, formative assessment, engineering education.*

Annotatsiya. Ushbu tezisda talabalarning texnik ijodkorligini rivojlantirish uchun loyiha-konstruktorlik topshiriqlari, raqamli prototiplash va shakllantiruvchi baholash integratsiyasiga asoslangan metodik yondashuv yoritiladi. Taklif etilgan model muammoni aniqlash, g'oya yaratish, prototiplash, sinov va refleksiya bosqichlarini yagona o'quv sikliga birlashtiradi va mustaqil fikrlash hamda muhandislik qaror qabul qilishni kuchaytiradi.

Kalit so'zlar: *texnik ijodkorlik, loyiha-konstruktorlik vazifalari, raqamli prototiplash, shakllantiruvchi baholash, muhandislik ta'limi.*

Аннотация. В тезисе раскрывается методический подход к развитию технического творчества студентов на основе интеграции проектно-конструкторских заданий, цифрового прототипирования и формирующего оценивания. Предлагаемая модель объединяет этапы постановки проблемы, генерации идей, прототипирования, испытания и рефлексии в единый учебный цикл и усиливает самостоятельное мышление и инженерное принятие решений.

Ключевые слова: *техническое творчество, проектно-конструкторские задания, цифровое прототипирование, формирующее оценивание, инженерное образование.*

At the current stage of higher education, technical training can no longer be reduced to the transmission of ready-made knowledge and the reproduction of standard procedures. A modern specialist is expected not only to understand formulas, mechanisms, and technological operations, but also to generate new technical ideas, improve existing solutions, and adapt designs to concrete production and social conditions. In an innovation-driven economy, employers need graduates who can identify a problem, compare design options, justify their choice, and transform an idea into a workable technical product. Likewise, OECD materials related to PISA 2022 interpret creative thinking as the capacity to generate, evaluate, and improve ideas in different contexts [1]. This means that technical creativity should be understood not as an accidental personal trait, but as a purposeful learning outcome that can be designed, supported, and assessed within university instruction.

Despite this demand, many technical disciplines still operate within a predominantly reproductive didactic model. Students are often trained to follow a pre-given algorithm, reproduce a sample drawing, or arrive at one correct answer as quickly as possible. Such organization may be effective for checking basic procedural literacy, yet it offers little opportunity to interpret an open problem, compare several alternatives, or balance functionality, safety, cost, manufacturability, and efficiency. Cropley shows that an excessively narrow concentration on rigid technical specifications may shrink the pedagogical space needed for creativity in engineering education. As a consequence, laboratory and practical tasks are frequently perceived by students as routines for confirming theory rather than as opportunities to explore, invent, test, and redesign.

The deeper reason for this situation is methodological. In many curricula, technical creativity is declared at the level of educational goals, but it is not systematically embedded in lesson design, task structure, digital tool selection, or assessment criteria. The traditional sequence of explanation, demonstration, practice, and final control rarely leads students through the full cycle of problem framing, idea generation, modelling, testing, error analysis, and improvement. Kuppuswamy and Mhakure argue that project-based learning gives engineering students access to design experiences that are much closer to professional practice [2]. However, simply adding a project assignment is not enough. If the project lacks explicit interim criteria, digital traces of thinking, and structured formative feedback, strong students benefit while others remain passive executors of instructions.

For this reason, I propose a four-stage methodological model that integrates project-design tasks, digital prototyping, and formative assessment. The first stage is problem framing and motivation. At this stage, the teacher offers an authentic technical task whose solution is not predetermined, but whose constraints are clearly specified. In a course such as engineering graphics, electronics, or applied mechanics, students may be asked to design a low-cost and safe device element, redesign an existing part in order to reduce material consumption, or develop a sensor-based control scheme under specific dimensional and energy limits. The key condition is that the task must allow at least two or three feasible solutions and must include explicit criteria such as size, weight, cost, durability, safety, energy consumption, or ease of manufacturing.

The second stage is idea generation and the design of alternatives. At this point, students should not move directly to one allegedly correct answer. Instead, they are required to create several possible variants and to document their design logic in an individual design journal or portfolio. It is methodically useful to demand at least three alternative sketches, structural schemes, or functional models from each student before the selection stage begins. The teacher supports ideation through guiding questions, morphological tables, reverse-engineering prompts, and "what if?" tasks that force students to reinterpret the initial conditions. Here novelty is judged together with feasibility. Technical creativity does not mean producing an unusual but unusable object; it means developing a solution that is both original and technically justified. In this way, students learn that creativity in engineering is inseparable from functionality, economy, and technological realism.

The third stage is digital prototyping and testing, which forms the core of the proposed methodology. At this stage, an idea becomes a visible and verifiable model: a technical drawing, a 2D or 3D object, an electrical circuit, an algorithm, a simulation result, or a virtual laboratory prototype. Bereczki and Karpati demonstrate that digital technologies can scaffold idea development, support creative production, and make learning processes observable [3]. Therefore, tools such as AutoCAD, Tinkercad, Fusion 360, Proteus, GeoGebra, or similar resources should be selected not because they are fashionable, but because they correspond to a concrete didactic goal. For example, when students design a small automatic irrigation system, they may first compare several circuit schemes, then test component interaction in a digital environment, detect errors, revise parameters, and only after that build a simplified prototype. This reduces waste of time and materials while enabling repeated safe experimentation and evidence-based design improvement.

The fourth stage is reflection and formative assessment. Black and Wiliam argue that assessment improves learning only when it functions as information for the next instructional step rather than as a mere record of the final result [5]. Therefore, technical creativity should be assessed not only through the finished product but also through the process by which the product was created. I propose four core criteria: the novelty of the technical idea, the functional and technological validity of the solution, the quality of the digital model or prototype, and the student's ability to justify design decisions with evidence. Assessment should occur at several checkpoints: initial problem analysis, first sketch, simulation result, revised model, final prototype, and oral defense. At each point, the teacher provides short but precise feedback indicating which requirements have been met, what technical risks remain, and what should be changed in the next iteration. Such an approach teaches students to treat error not as a sign of failure, but as a resource for constructive redesign.

The proposed model can be applied across different technical disciplines while preserving the same didactic logic. In a mechanics course, students may design a support structure with minimal material consumption under a given load. In electronics, they may create a monitoring or alarm device for a defined environmental parameter. In technological machinery, they may suggest a simplified transfer mechanism for a particular production operation. In each case, the sequence remains stable: describe the need, define the constraints, produce several alternatives, build a digital model, test the solution, and defend the chosen version. This consistency transforms project work from a random creative exercise into a manageable pedagogical process. The instructor does not provide a ready-made answer; instead, the instructor clarifies the logic of selecting and defending a technical decision. That is precisely what brings the academic task closer to the real structure of engineering activity [2].

The effectiveness of this methodology cannot be judged solely by looking at the final product. Monitoring should include at least five indicators: the ability to reinterpret the problem, the number and quality of alternatives produced, the number of iterations in the digital model, the level of technical justification provided by the student, and the quality of the error-cause-correction chain documented in the portfolio. At the beginning and end of a semester, students may be given equivalent open technical tasks, and their portfolios can then be compared. Such monitoring makes it possible to identify the exact stage at which additional pedagogical support is required. If a student can generate many ideas but cannot justify the choice, reflective prompts and peer review should be strengthened. If a promising idea exists but the model remains weak, then additional support in digital prototyping is needed. In this sense, formative assessment does not end with marking; it defines the direction of the next improvement step [5].

Within this model, the teacher is not the only source of knowledge but a facilitator and expert who professionalizes the learning task. The teacher formulates the problem in a realistic way, specifies the constraints, asks clarifying questions, provokes comparison among alternatives, and cultivates a culture of evidence-based technical reasoning. This shift is essential. Excessively directive teaching suppresses creative risk, while a completely uncontrolled environment leads to aimless activity. The proposed methodology is therefore based on the principle of guided autonomy: students search for solutions independently, but the decision-making process is accompanied by clear criteria, digital traces, and timely feedback. Because digital tools make the design process visible, the teacher can evaluate not only the final answer but also the trajectory by which the idea matured into a prototype [3].

The success of the proposed approach depends on several didactic conditions. First, the task must remain open and professionally meaningful: students should understand not only what they are designing, but why such a solution matters. Second, individual and collaborative work must be balanced, because technical creativity requires both personal initiative and collective discussion. Third, students should leave a digital trace of their thinking: sketches, variant tables, screenshots of simulations, logs of errors and corrections, and short reflective notes. Fourth, the final defense should focus not only on the product but on the logic of decision-making. Xu and colleagues show that the integration of maker education and design thinking can strengthen both knowledge outcomes and creative tendencies [4]. Consequently, the methodology for developing students' technical creativity should be built as a unified cycle that combines theoretical knowledge, design practice, and formative assessment into one pedagogical system.

For doctoral research, the value of the proposed model lies in its measurability. Unlike abstract calls for creativity, the model generates observable indicators: the number of alternatives proposed, the depth of redesign, the quality of digital simulation, the strength of technical argumentation, and the stability of improvement across successive iterations. This makes the approach suitable for comparing traditional instruction with an experimental methodology. Its effectiveness may be examined through portfolio analysis, rubric-based expert assessment, pre- and post-task comparison, and student reflection protocols. Such a design allows the researcher to determine not only whether technical creativity has increased, but also which stage of the instructional cycle produces the strongest pedagogical effect. In this sense, the model has both didactic and research significance: it supports everyday teaching practice and provides a clear empirical framework for dissertation-level validation.

In conclusion, the improvement of methodology for developing students' technical creativity requires a transition from the reproduction of ready-made answers to the structured solution of open technical problems. The model proposed in this thesis - based on project-design tasks, digital prototyping, and formative assessment - makes it possible to organize technical creativity as a staged pedagogical result rather than as a spontaneous talent. As a result, students strengthen independent thinking, alternative-based decision-making, analysis of technical errors, prototyping skills, and the ability to defend their ideas with evidence. This gives the dissertation topic on improving the methodology of students' technical creativity a concrete pedagogical and practical foundation.

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