PEDAGOGICAL AND PSYCHOLOGICAL FOUNDATIONS FOR DEVELOPING INVENTIVE ABILITIES OF FUTURE ENGINEERS IN A DIGITAL TRANSFORMATION ENVIRONMENT

Turakulova Marjona Kiyom kizi
Associate Professor at Bukhara State Technical University

ABSTRACT

This article analyzes the pedagogical and psychological foundations for developing the inventive abilities of future professionals in engineering education under digital transformation conditions. It substantiates the content of inventive ability and the role and influence of digital technologies in its formation. Methodological approaches and pedagogical conditions for effectively organizing this process are also highlighted.

Keywords: Digital transformation, engineering education, inventive ability, pedagogical-psychological foundations, innovative technologies.

INTRODUCTION

Digital transformation processes are deeply rooted in modern industry and the economy. In the engineering field, technologies such as automation of production, artificial intelligence, Internet of Things (IoT), and cyber-physical systems pose new requirements for engineers. At the same time, inventive ability is becoming one of the most crucial competencies in engineering activity. Developing inventive abilities during the preparation of future engineers in a digital transformation environment is not only an integral part of professional training but also a pressing scientific and practical task for the education system.

Inventive ability is a combination of intellectual, emotional, and motivational resources aimed at creating new, original, and practically useful ideas.

Definition of Inventive Ability

Inventive ability is a system of mental characteristics that integrate analytical, synthetic, divergent and convergent thinking, imagination, independent decision-making, and innovative activity. It serves to advance new technological, scientific, or practical ideas and implement them as real solutions.

Main components of inventive ability:

Analytical abilities (problem analysis, distinguishing situations);
Synthetic abilities (combining new ideas);
Critical thinking;
Divergent thinking;
Motivational component (striving for novelty, intrinsic interest);
Metacognitive competencies (self-assessment and self-regulation).
Theoretical Background and Scientific Views

J.P. Guilford (USA) interpreted inventive ability as the capacity for divergent thinking aimed at generating socially beneficial new ideas. He emphasized:
Fluency (ability to generate many ideas);
Flexibility (thinking in various directions);

Originality (novel solutions);
Elaboration (ability to develop ideas in detail).

E.P. Torrance (USA) defined inventiveness as the ability to generate novelty, flexibility, and nontraditional solutions. He developed the Torrance Tests of Creative Thinking (TTCT) and considered inventiveness a process that can be developed, not just an innate talent.
Mihaly Csikszentmihalyi (Hungary–USA) considered inventiveness as the interaction of:
The individual (creator);
The field (professional community, experts);
The domain (cultural-knowledge sphere).

Howard Gardner (USA) related inventiveness to his theory of multiple intelligences, asserting that creativity may manifest in various types of intelligence (e.g., visual, musical, logical).

S.L. Rubinstein noted that inventiveness is defined by the conscious and motivational nature of activity.

A.N. Leontiev argued that inventiveness is formed within the structure of activity, involving motive, goal, means, and outcome.

Ya.A. Ponomaryov viewed inventiveness as the ability to adapt past experiences to new situations during thinking processes.

V.N. Druzhin considered inventive ability as the capacity to find original and effective solutions in problematic situations. He developed problem-based learning methodologies.

V.S. Mukhina studied children's and adolescents' creative abilities and identified age-related stages of creative activity development.

M.M. Jo'rayev (Uzbekistan) described inventive ability as the capacity to solve problems in new, original, and effective ways. He emphasized problem-based learning and project activities as tools for developing this ability.

Z.N. Kobilova (Uzbekistan) regarded inventive ability as a key competence for professional activity, linking it with skills such as complex analysis, proposing innovative solutions, teamwork, and communication.

A.A. Abduqodirov (Uzbekistan) interpreted inventiveness as the psychological basis of innovative activity. He emphasized the importance of problem-based teaching methods, independent inquiry, and argumentation skills.

Sh.S. Yusupova (Uzbekistan) defined inventive ability as striving for novelty, independent thinking, and unconventional problem-solving. She supported using virtual labs, simulations, and online project activities in digital learning environments.

J.M. Abdurakhmonov (Uzbekistan) connected inventiveness in engineering education with an industrial-innovative approach. He advocated for engaging students in real industry problems and using digital platforms for prototyping and modeling.

Materials and Methods of Research. Digital Transformation Environment and Its Impact. The digital transformation environment in education involves the comprehensive use of digital technologies, platforms, and services to fundamentally change teaching content, forms, and methods.

In engineering education, it enables:
Virtual and augmented reality-based labs;
Simulation and modeling systems;
Distance and hybrid learning formats;
AI-based adaptive learning systems;
Collaborative environments and digital project platforms.

These tools foster the ability to solve engineering problems in digital form and create a new context for creative activity.

Pedagogical and Psychological Foundations
To develop inventive abilities in this context:
Learner-centered approach – considering individual abilities, interests, and development pace.

Activity-based learning – using project- and problem-based methods tied to real-world industry tasks.

Digital pedagogical design – purposeful use of digital resources and effective communication in online/hybrid formats.

Motivational strategies – encouraging intrinsic motivation (engaging tasks, self-awareness) and extrinsic motivation (rewards, certification, recognition).

Psychological support – managing stress, fostering reflection, and building social-psychological skills for teamwork.

The digital transformation environment is a system of organizational and pedagogical conditions created to develop students' knowledge, skills, and competencies through the integration of digital platforms, tools, services, and resources into the educational process.

Digital tools and platforms include, for example, Learning Management Systems (such as Moodle, Google Classroom), artificial intelligence systems, and virtual laboratories.

Interconnection and integration – all educational resources and processes are digitally connected.

Adaptivity and flexibility – the ability to adjust to the individual needs of each student.

Application of innovative technologies – such as virtual/augmented reality, the Internet of Things (IoT), Big Data, and Artificial Intelligence (AI).

Support for distance and hybrid learning formats – the educational process is no longer limited by time or place.

Pedagogical goals of the digital transformation environment: To improve the quality of education;
- to organize personalized and adaptive learning;
- to develop modern competencies (digital literacy, problem-solving, inventive thinking).
- examples of application: In engineering – virtual laboratories, simulators, 3D modeling software;
- in medicine – telemedicine platforms, VR training programs;

In business – CRM systems, online services, AI-powered decision-making systems.
Functions of the digital transformation environment in engineering education:
- teaches how to solve engineering problems in digital formats;
- prepares students for real industrial systems;
- develops innovative thinking and inventive abilities;
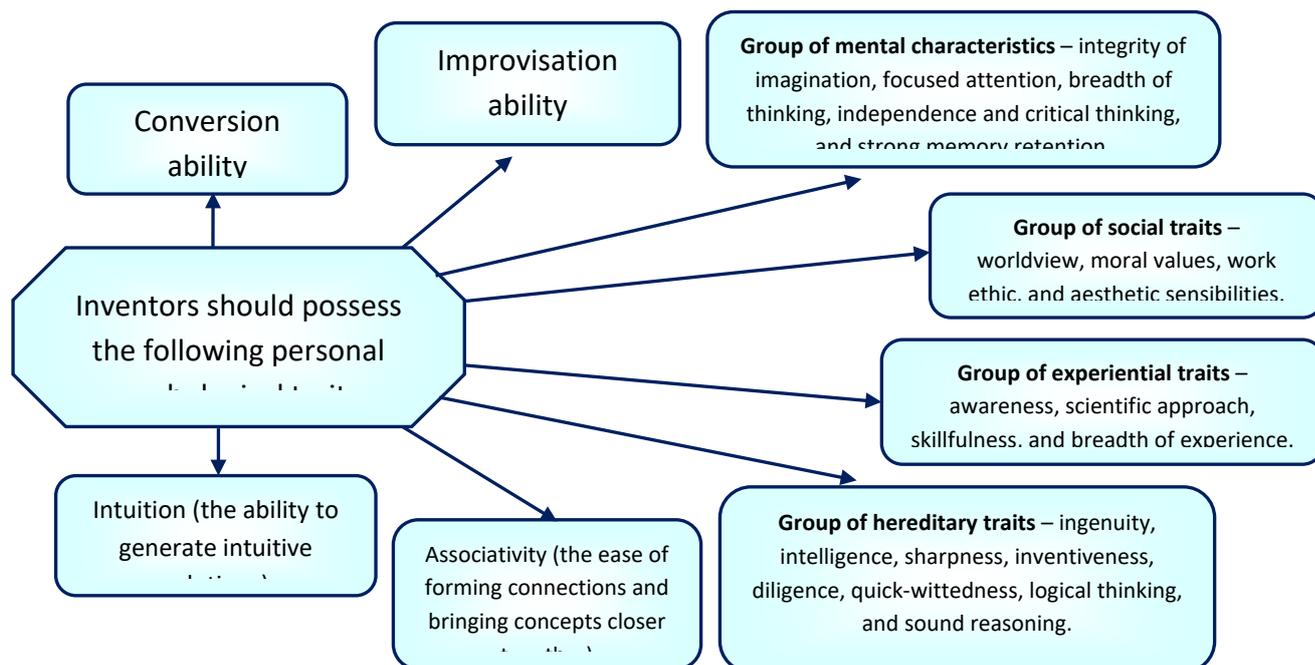- builds skills for remote and collaborative work.

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Figure 1. Psychological Characteristics of an Inventive Person

Results and Discussion

Methodological Approaches: problem-based learning – directing students to solve problems through research and investigative approaches, project-based learning – fostering practical and creative activities through both group and individual projects.

Simulation and modeling – analyzing complex engineering systems in a virtual environment. Gamification – incorporating game elements into the learning process to make it more engaging and motivational, distance and hybrid learning – enabling collaboration with global experts and access to unlimited educational resources.

Research Methodology A comparative study was conducted involving two groups of undergraduate students:

Experimental Group (EG): students trained using a methodology aimed at developing inventive abilities in a digital transformation environment.

Control Group (CG): students trained using traditional teaching methods.
The analysis was carried out in the following directions:
- ✓ quantitative analysis – based on results from creativity tests, divergent thinking assessments, and project work scores (Tables 1, 2, and 3).
- ✓ qualitative analysis – through interviews with students and instructors, observations, and portfolio analysis.

Table 1. **Quantitative Analysis – Results of Inventive Ability Tests**

Indicator	Experimental Group (n=30)	Control Group (n=30)
Average Score (max 100)	84.5	68.2
Standard Deviation	6.3	8.7

Analysis: Students in the experimental group demonstrated significantly higher results in inventive ability compared to the control group ($p < 0.05$).

Table 2. **Divergent Thinking Test Results**

Indicator	Experimental Group	Group Control Group
Idea Fluency	18.4	12.1
Flexibility	16.7	11.8
Originality	17.3	10.5

Divergent thinking indicators were significantly higher among students in the Experimental Group (EG).

Table 3. **Project Work Evaluations**

Indicator	Experimental Group (n=30)	Control Group (n=30)
Average Score (max 100)	91.2	76.5

Note: The quality of creative project work was higher in the Experimental Group. Qualitative Analysis Results – Student Feedback:
- it became easier to visualize their ideas with the help of digital technologies.
- online platforms facilitated teamwork.
- working on projects in remote and hybrid formats encouraged them to find multiple solution options.

Teacher Feedback:
- students showed significant development in independent thinking, analyzing problem situations, and proposing creative solutions.
- the use of digital tools increased motivation and reduced social-psychological barriers.

Portfolio Analysis:
➢ the works of students in the experimental group (eg) featured numerous original designs, innovative solutions, and digital models.
➢ the control group (cg) students predominantly presented conventional and repetitive solutions.

CONCLUSION

Developing inventive abilities in future engineers under digital transformation requires a renewed pedagogical-psychological perspective. Learner-centered teaching, activity-based methods, and integration with digital technologies are crucial. In innovative learning environments, collaboration between teachers and students fosters creative thinking. Students trained with the inventive development methodology achieved better results in decision-

making, divergent thinking, and project-based innovation. They also developed teamwork skills via digital platforms.

These outcomes prove the effectiveness of this methodology in preparing engineers with inventive abilities who meet the demands of the digital economy and Industry 4.0.

REFERENCES

1. President of the Republic of Uzbekistan. (2017, February 7). Decree No. PF-4947 on the Strategy of Actions for the Further Development of the Republic of Uzbekistan. Collection of Legislative Acts of the Republic of Uzbekistan. Tashkent.

2. Turakulova, M., Tilloev, L., Murodov, M., Ataullaev, S., & Savriev, M. (2024). Extraction of hydrocarbons from "yellow oil" with liquefied gas residue. E3S Web of Conferences, 486, 04023. EDP Sciences. https://doi.org/10.1051/e3sconf/202448604023

3. Turakulova, M.K. (2019). Selection of types and tools of education in working with gifted students. Pedagogical Mastery. Scientific-theoretical and methodological journal, Bukhara, (5), 191.

4. Turakulova, M.K. (2021). Mechanism and model for developing technical creativity of gifted students in higher education institutions. Bulletin of the National University of Uzbekistan (NUUz), No. 1/6. Tashkent.

5. Turakulova, M.K. (2022). Personality creativity and cognition in the formation of students' technical creativity. Bulletin of the National University of Uzbekistan, No. 1/2. Tashkent.

6. Turakulova, M.K. (2021). Priority tasks in the system of higher education. VII Scientific-Methodical Journal of "Scientific Progress", Proceedings of the International Scientific-Practical Distance Conference "The 21st Century Skills for Professional Activity".

7. Turakulova, M.K. (2021). Development of technical creative thinking skills of gifted students. World Bulletin of Social Sciences, 14.

8. Turakulova, M.K. (2022). Scientific and creative training of teachers in the formation of technical creativity of talented students. International Congress on Multidisciplinary Studies in Education and Applied Sciences. Malaysia.

9. Turakulova, M.K., & Rakhmonov, K.S. (2020). Identification and development of the abilities and creativity of gifted students in higher educational institutions. Asian Journal of Multidimensional Research, Special Issue.

10. Turakulova, M.K., & Rakhmonov, K.S. (2020). Search, selection, and planning of targeted training of talented students in technical universities. International Engineering Journal for Research & Development, 5.

11. Fatullayeva S.I. Oliy ta'limda fanlar integratsiyasini ta'minlash muammolari. International conference pedagogical reforms and their solutions Volume 4, Issue 2, 2024. P.27-30.

12. Fatullayeva S.I. Improving dual education by solving the problem of subject integration. International conference pedagogical reforms and their solutions Volume 4, Issue 2, 2024. P.22-26.

13. Turakulova, M.K., & To'xtayeva, Z.Sh. (2021). Increasing the effectiveness of education through active learning methods. In Proceedings of the Republican Scientific-Practical Conference "Innovative Solutions of Science-Education and Production in the Light Industry", Vol. 1. Bukhara.