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PEDAGOGICAL CONDITIONS FOR DEVELOPING PRACTICAL SKILLS OF FUTURE ENGINEERS BASED ON PROGRAMMED EDUCATIONAL TOOLS

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Annotations: This article discusses the importance of programmed learning tools in preparing engineering students for practical work and the pedagogical conditions necessary for their effective use. Factors such as the integration of modern technologies in the educational process, interactive and contextual learning, and the new role of the teacher are important factors in improving the quality of engineering education. Engineering education plays a crucial role in addressing global technological and industrial challenges. In an era defined by rapid advancements in technology and increasing complexity in industrial systems, the demand for skilled engineers continues to rise.

Keywords: engineering education, programmed learning tools, practical skills, pedagogical conditions, interactive learning.

Nowadays, digitalization in education has taken a leading position in the world. In this regard, in our republic, in order to determine the priority areas of systematic reform of higher education, to raise the process of training highly qualified personnel with modern knowledge and high spiritual and moral qualities, and to think independently, to a qualitatively new level, to modernize higher education, and to develop the social sphere and economic sectors based on advanced educational technologies, the Decree of the President of the Republic of Uzbekistan No. PF-5847 dated October 19, 2019 “On approval of the Concept for the Development of the Higher Education System of the Republic of Uzbekistan until 2030” was adopted. In order to consistently ensure the implementation of the tasks set out in the Concept for the Development of the Higher Education System of the Republic of Uzbekistan until 2030, as well as to expand the independence of higher education institutions, sharply reduce state administrative management in their activities, and thereby form HEIs that train highly qualified personnel who can meet the requirements of the changing labor market, this system was introduced in 35 higher education institutions starting from January 2022, based on the Resolutions of the President of our Republic dated December 24, 2021 “On additional measures to ensure the academic and organizational and managerial independence of state higher education institutions” and “On measures to provide financial independence to state higher education institutions”.

Engineering education plays a crucial role in addressing global technological and industrial challenges. In an era defined by rapid advancements in technology and increasing complexity in industrial systems, the demand for skilled engineers continues to rise. These professionals are expected to drive innovation, develop sustainable solutions, and tackle complex problems that shape the modern world. Universities, as the primary institutions responsible for preparing future engineers, face the critical task of equipping students with the necessary skills and knowledge to succeed in this dynamic and competitive environment. Achieving this goal requires a holistic approach to education that extends beyond traditional theoretical instruction.Despite the recognized importance of engineering education, universitiesoften encounter significant challenges in preparing students to meet professional demands. One of the primary issues lies in the disconnection between academic programs and the expectations of the industry. Many engineering curricula prioritize theoretical knowledge while placing insufficient emphasis on the development of practical skills and real-world problem-solving abilities. As a result, graduates frequently find themselves underprepared to navigate the complexities of their professional roles. Furthermore, the rapid pace of technological advancement poses an additional challenge, as educational programs struggle to keep their content aligned with the latest industry developments. Another pressing concern is the insufficient focus on soft skills, suchas communication, teamwork, and leadership, which are increasingly essential for engineers working in collaborative and interdisciplinary environments.

The pedagogical conditions for developing practical skills of future engineers using programmed educational tools involve creating an educational environment that effectively integrates technology with didactic principles to foster hands-on competence. Here's a structured overview of those conditions:

Alignment with Educational Objectives

This is a concept where learning activities, content, and assessments are designed to clearly match the goals and skills that an educational program wants students to achieve. Educational Objectives are the specific skills, knowledge, attitudes, or abilities that a course or program wants students to gain. Alignment means that lessons, activities, assignments, and exams are directly tied to these objectives — not random or unrelated. Why it's important: Good alignment ensures students aren't wasting time on material that doesn't help them meet the goals, and teachers can better measure if learning is really happening.

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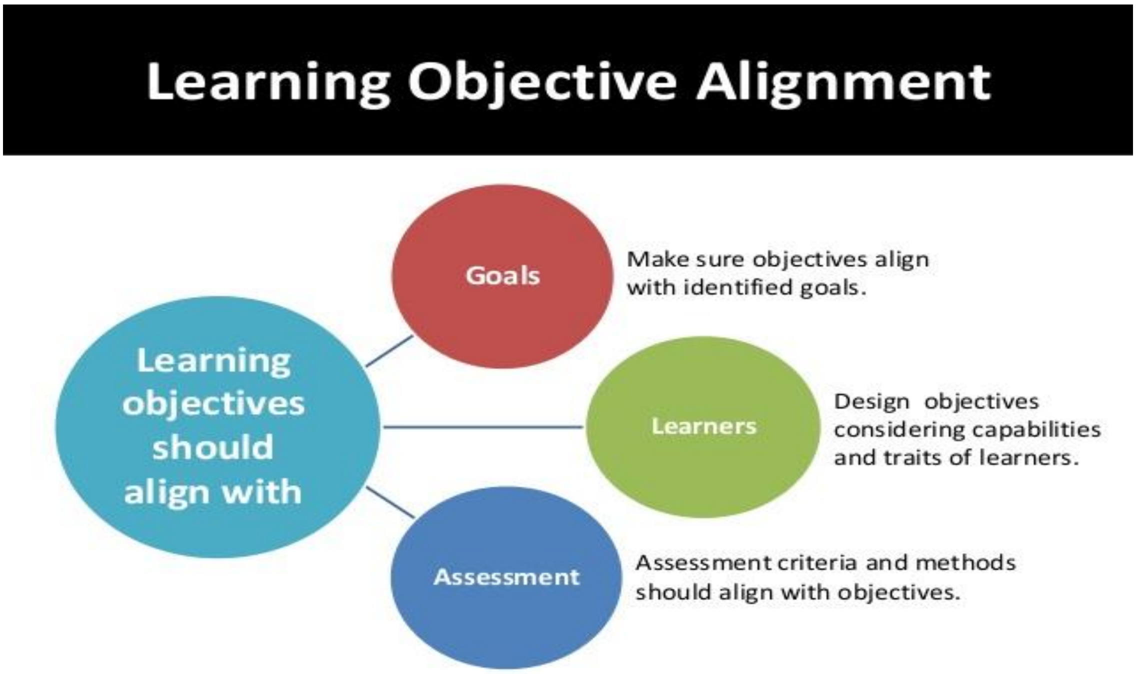

Competency-Based Approach: Tools should be designed to meet specific engineering competencies (e.g., problem-solving, system thinking, technical proficiency). The Competency-Based Approach (CBA) is a style of education focused on helping learners master specific skills or competencies rather than just spending time in a classroom or completing a set number of courses.Here's the core idea:Competencies are clearly defined — what a student must know and be able to do.Progress is based on mastering these competencies, not on time spent learning (so students can move faster or slower depending on their ability).Assessment is ongoing and authentic — students must demonstrate they can apply what they've learned, often through real-world tasks.Learning is personalized — different students might use different learning paths to achieve the same competency.

Outcome-Oriented Design: Learning outcomes should clearly define what practical skills students are expected to develop. Outcome-Oriented Design is an educational planning approach where everything — courses, activities, assessments — is built starting from the end goals you want students to achieve.In simple terms:You first define the desired outcomes (the knowledge, skills, or behaviors students should demonstrate by the end of the program).Then, you design the learning experiences backwards from those outcomes.Everything taught, practiced, and assessed is purposefully aimed at achieving those outcomes.This method makes sure that education isn't just about covering content, but about ensuring students can actually perform or apply what they've learned.Example:If the outcome is "Students can critically analyze media sources for bias," the course would include activities like media analysis, debates, and real-world evaluation projects — not just memorizing definitions of bias.Key Features:Focused on measurable, real-world skills.Clear connection between teaching, activities, and goals.Helps students and teachers stay clear about what success looks like.It fits very closely with the Competency-Based Approach and Alignment with Educational

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Objectives that you mentioned earlier — they all emphasize clear goals and meaningful learning.

Integration of Programmed Tools into Curriculum.Curricular Embedding: Programmed tools must be embedded into the learning process, not used as add-ons.Progressive Complexity: Tasks and simulations should increase in complexity to mirror real-world engineering challenges. Integration of Programmed Tools into Curriculum means deliberately using digital tools, software, or structured learning platforms as part of how a course or program is taught — not just as an add-on, but as a core part of the learning experience.Here's what it typically involves:Choosing the right tools that support the educational objectives and outcomes (like learning management systems, simulation software, coding platforms, AI tutors, virtual labs, etc.).Embedding them into learning activities, not just offering them separately. For example, students might use a digital chemistry simulation during a science unit instead of reading only about experiments.Aligning tool use with competencies and outcomes — so that every tool directly helps students develop the skills they are supposed to master.Supporting teachers and students with training or tutorials so they can use the tools effectively.Example:In a language course, instead of just giving grammar lessons, students might regularly use a programmed tool like Duolingo for Schools to practice — and their progress on the app might count toward demonstrating fluency competencies.Why it matters:Makes learning more engaging and interactive.Can personalize and adapt learning for different student needs.Prepares students for real-world environments where technology is essential.

Active Learning Environment.Learning by Doing: Emphasis on interactive simulations, virtual labs, and task-based learning to foster hands-on experience.Project-Based Learning: Students work on real or simulated engineering problems using programmed tools. An Active Learning Environment is a classroom or learning setting where students are actively engaged in the learning process — rather than just sitting, listening, and absorbing information

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passively.In active learning:Students participate through discussions, problem-solving, case studies, group work, simulations, hands-on activities, debates, or projects.Interaction is key — between students, between students and teachers, and sometimes even between students and digital tools.The focus is on students doing, thinking, questioning, and creating, not just remembering facts.Example:Instead of lecturing about ecosystems, a teacher might have students build their own mini-ecosystems, monitor changes, and then analyze and present their findings.Benefits:Helps students develop deeper understanding.Encourages critical thinking and collaboration.Makes learning more memorable and fun.Aligns naturally with competency-based and outcome-oriented education models.In short, it shifts the center of the classroom from the teacher to the learner.

Individualization and Adaptability

Adaptive Learning Paths: Systems should tailor content based on individual student progress and understanding.Feedback Mechanisms: Immediate and detailed feedback helps correct errors and reinforce learning. Individualization and Adaptability in education mean shaping the learning experience to fit the unique needs, pace, strengths, and interests of each student, rather than forcing everyone to learn in exactly the same way or at the same speed.Here's what each term points to:Individualization: Tailoring what or how a student learns based on their personal needs. For example, one student might need more practice with writing, while another might be ready for advanced work in math. Adaptability: Being flexible — adjusting teaching methods, materials, assessments, and even goals based on how students are progressing in real time. Technology often helps here (like adaptive learning platforms that adjust difficulty automatically).In Practice:Students might work on different tasks during class, depending on their skill levels.A teacher might offer multiple ways to learn the same material (videos, readings, hands-on activities).Assessments might allow students to show mastery in different ways (presentation, project, test, etc.).Why it matters:Every learner is different.Increases student motivation and success.Supports a competency-based and outcome-oriented system by ensuring all students can meet the goals — just in their own way and time.

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Instructor Facilitation and Support

Pedagogical Training: Instructors must be trained in using programmed tools effectively.Mentorship Role: Teachers shift from content delivery to facilitators of skill development. Instructor Facilitation and Support refers to the role teachers (or trainers) play in guiding, motivating, and assisting students as they learn — rather than just delivering content.In this role:The instructor becomes more of a coach or mentor than a traditional lecturer.They create an environment where students feel safe to ask questions, make mistakes, and explore ideas.They guide discussions, ask powerful questions, provide timely feedback, and help students reflect on their learning.They adjust instruction based on student needs (connecting to adaptability and individualization).They support skill development, not just content memorization — crucial for competency-based and outcome-driven education.

Access to Modern Technologies.Up-to-Date Software/Hardware: Access to tools that reflect current industry standards (e.g., CAD/CAM, MATLAB, Simulink, PLC simulators).Digital Infrastructure: Reliable networks, computing resources, and IT support. Access to Modern Technologies in education means ensuring that students and instructors have the tools, devices, software, and internet resources they need to engage fully in today's digital learning environments.It involves:Providing hardware like laptops, tablets, smartboards, VR headsets, or lab equipment.Offering software and platforms like learning management systems (LMS), digital libraries, simulation tools, AI tutors, or collaboration apps.Ensuring connectivity, meaning fast and reliable internet access for all students, both in and outside of school.Teaching digital literacy skills, so students not only use the tools but use them wisely, safely, and effectively.

Assessment of Practical Skills.Performance-Based Assessment: Use of simulations and projects to evaluate practical capabilities.Automated Assessment Tools: Incorporate systems that can track student interactions and evaluate efficiency, accuracy, and problem-solving strategies. Assessment of Practical Skills is about evaluating what students can actually do — not just what they know in theory.In practical skill assessment:Students demonstrate their abilities through real-world tasks, projects, performances, experiments, presentations, or simulations.Assessment focuses on application of knowledge, problem-solving, technique, and competency.It often uses rubrics with clear criteria to judge how well the skill was performed.Examples:In nursing: students might be assessed on performing a patient check-up in a simulation lab.In computer science: students might build a working app rather than just writing about app development.In art: students might create a portfolio of original works to show their technique and creativity.

Motivation and Engagement

Gamification Elements: Introduce badges, points, and challenges to keep students engaged.Real-World Relevance: Use case studies and problems based on real engineering contexts. Motivation and Engagement are about sparking students' interest and keeping them actively involved in their learning journey.Here’s the basic idea:Motivation is the internal drive that pushes students to learn — it can be intrinsic (learning because it's interesting or meaningful) or extrinsic (learning for rewards, grades, recognition).Engagement is the visible

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energy: students participating, asking questions, collaborating, creating, and putting in effort.Key ways to boost motivation and engagement:Make learning relevant: Connect topics to real-world applications or students' personal goals.Offer choice and autonomy: Let students have a say in projects, topics, or methods.Use active learning strategies: Discussions, games, projects, simulations, hands-on experiments.Provide regular feedback: Positive, constructive feedback builds confidence and keeps momentum.Set clear, achievable goals: Helps students see progress and stay committed.Create a supportive environment: When students feel safe and valued, they engage more deeply.

Interdisciplinary Collaboration

Collaborative Platforms: Tools should support team-based projects that mimic engineering work environments.Cross-Subject Integration: Encourage application of knowledge from math, physics, computer science, etc. Interdisciplinary Collaboration in education means bringing together knowledge, methods, and skills from multiple fields to solve problems, complete projects, or deepen learning.In this approach:Students (or instructors) work across different disciplines — like combining science and art, or business and technology — instead of staying inside one traditional subject silo.Collaboration encourages creative thinking, problem-solving, and real-world application, because most real-world challenges don't fit neatly into one subject.It helps students see connections between areas they might normally think are unrelated, building a more holistic understanding.

Additional Pedagogical Conditions and Considerations. Additional Pedagogical Conditions and Considerations refer to the **extra elements** educators should think about and set up to create an environment where students can truly succeed — beyond just curriculum and teaching methods.

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Constructivist Learning Environment.Learning Through Exploration: Programmed tools should allow students to explore, test, and apply concepts independently.**Scaffolding**: Gradual removal of support as students gain proficiency, implemented through layered levels in the software or simulation.

Contextual Learning.Industry-Inspired Scenarios: Tasks should simulate real-life engineering projects (e.g., bridge design, circuit creation).**Problem-Based Learning (PBL)**: Students use tools to address authentic engineering problems, enhancing relevance and engagement.

Continuous Professional Development (CPD) for Educators. Teachers need ongoing training not just in how to use the tools, but **how to integrate them pedagogically**.Communities of practice can support educators in sharing best practices for implementing programmed tools effectively.

Interactivity and Multimodality. Use **multimodal content** (text, animation, voice, video, interactive widgets) to cater to diverse learning styles.**Dynamic simulations** and **virtual reality (VR)** environments can be used to mimic hazardous or complex systems safely.

Data-Driven Personalization. Advanced tools can **collect and analyze learning data** to tailor tasks and recommend resources.Learning analytics can help instructors identify struggling students early.

Collaborative and Networked Learning.Cloud-based platforms allow remote collaboration on engineering projects.Tools like **AutoCAD Web**, **MATLAB Online**, or **GitHub** promote collaborative engineering work and peer learning.

Ethical and Societal Dimensions. Programmed tools can include modules that simulate ethical dilemmas or environmental impacts of engineering decisions.Embedding **social responsibility** in engineering education helps form well-rounded professionals.

Theoretical Foundations You Might Want to Explore.**Bloom's Taxonomy**: For developing learning objectives, especially in applying and analyzing stages.**Kolb's Experiential Learning Theory**: Supports the idea of learning through concrete experience and reflection.**Vygotsky's Zone of Proximal Development**: Supports scaffolding within programmed tools.**T. A. van Gog's Research on Worked Examples**: Useful in early stages of skill acquisition using programmed tools.

Conclusion**:**The use of programmed tools in engineering education is a necessity of the times. However, their effective use will serve to form the necessary practical skills in students only if the above pedagogical conditions are met. In this case, the functioning of the teacher, technical base and educational methodology as a whole system is an important factor.

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