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SOLUTIONS

DESIGN PRINCIPLES FOR SOFTWARE DEVELOPMENT
AIMED AT DEVELOPING 21ST CENTURY SKILLS

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Abstract. *This scientific thesis is devoted to the development of fundamental design principles for software aimed at developing 21st century skills (based on the 4K model). The research analyzes modern educational requirements, the essence of 4K skills, as well as the pedagogical and technical aspects of educational software design. The proposed system of principles includes learner-centeredness, interactivity and active participation, personalization, collaboration and social learning, interdisciplinary integration, assessment and feedback, flexibility and extensibility, and gamification. These principles serve as a theoretical and practical foundation for designing educational software that develops 21st century skills in academic lyceums.*

Keywords: *21st century skills, 4K model, software design, educational technology, design principles, academic lyceum, gamification, personalization.*

In the context of contemporary globalization and digital transformation, the education system faces fundamentally new demands. Modern learners are required not only to possess deep subject knowledge but also to master the skills necessary for successful functioning in a rapidly changing world. These skills are commonly referred to as "21st century skills" or the "4K" model (Critical thinking, Creativity, Communication, Collaboration).

Educational software can serve as a significant tool for developing 21st century skills. However, designing such software presents unique challenges: it must harmoniously integrate pedagogical objectives, technical capabilities, and user experience. Research indicates that the success of educational software depends on the organic connection between subject content (what to teach) and didactic strategies (how to teach).

The 21st century skills system constitutes a core component of the modern educational paradigm. These skills prepare learners for a complex, dynamic, and competitive world.

The 4K model encompasses four fundamental skills:

1. Critical Thinking — the ability to analyze information, evaluate evidence, draw logical conclusions, and solve problems systematically. This skill is closely related to the higher levels of Bloom's taxonomy (analysis, evaluation, creation).

2. Creativity — the capacity to generate new ideas, apply original approaches, and create innovative solutions. Creativity is essential not only in the arts but across all scientific, technical, and professional domains.





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3. Communication — the ability to express ideas clearly and effectively, listen actively, and exchange information through various media and formats. This encompasses oral, written, digital, and visual communication.

4. Collaboration — the competence to work effectively in teams, distribute responsibilities, consider diverse perspectives, and cooperate toward common goals.

Some models expand the 4K skills to include additional competencies. For instance, the Four-Dimensional Education model encompasses the following domains :

- **Knowledge** — interdisciplinary content, foundational concepts;
- **Skills** — competencies based on the 4K framework;
- **Character** — mindfulness, curiosity, courage, resilience, ethics, leadership;
- **Meta-Learning** — metacognition, growth mindset.

This expanded approach requires a comprehensive methodology when designing software for developing 21st century skills.

Design-Based Research (DBR) is one of the most widely applied methodologies in the field of educational technology. DBR focuses on designing practical interventions in real educational settings and involves continuous iteration between the stages of design, implementation, and evaluation .

Key principles of DBR:

- Integration of theory and practice throughout the design process;
- Continuous system improvement based on user feedback;
- Consideration of all contextual factors in the educational environment.

The educational design process is grounded in several pedagogical principles :

1. **Goal-oriented principle** — clear definition of learning objectives and alignment with them;
2. **Reflective principle** — continuous analysis and improvement of the educational process;
3. **Outcome-based principle** — orientation toward measurable, tangible results;
4. **Multi-factor principle** — consideration of all factors affecting the educational process;
5. **Learner-centered principle** — adaptation to learners' individual characteristics;
6. **Sequential principle** — implementation of the design process in consistent stages.

Designing educational software requires particular attention to the following aspects :

- **User needs analysis** — identifying the real needs of learners and teachers;
- **Didactic structuring of content** — organizing materials logically and pedagogically;
- **Interface and user experience** — creating intuitive, convenient designs that support the learning process;
- **Assessment and feedback mechanisms** — enabling continuous monitoring of learner progress and providing timely feedback.





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The following section presents a systematic exposition of the core principles for designing software aimed at developing 21st century skills.

Software must be designed considering the age, psychological, and cognitive characteristics of learners. Academic lyceum students (aged 15-17) are in a period of developing abstract thinking, self-awareness, and professional self-determination; therefore, the software should foster their independence, research abilities, and creativity .

Software should include interactive elements that ensure active learner participation, mutual interaction, and responsible engagement with the learning process . This principle directly develops learners' 4K skills.

Software should be adaptable to each learner's knowledge level, learning pace, and interests . Adaptive learning systems account for individual characteristics and offer personalized learning pathways.

Software should support collaboration among learners, exchange of ideas, and joint problem-solving . This principle develops collaboration and communication skills.

Software should demonstrate connections between different subject areas, helping learners develop comprehensive knowledge . This principle fosters systematic and critical thinking.

Software should enable continuous assessment of learners' knowledge and skills, providing timely feedback . This principle develops self-assessment and metacognitive skills.

Software must be capable of adapting to changing educational requirements and technological innovations, allowing for the addition of new modules and functions .

Gamification elements increase learner motivation and make the learning process engaging. Research shows that gamification is an effective tool for developing 21st century skills .

Implementation of the proposed principles involves the following stages:

Stage 1: Needs Analysis — identifying the needs of learners, teachers, and other stakeholders. This stage examines the current level of learners' 21st century skills, deficiencies in existing software, and directions for improvement.

Stage 2: Conceptual Design — developing the conceptual architecture of the software based on the principles outlined above. Educational content, interface, and interaction mechanisms are described in detail.

Stage 3: Prototyping and Testing — creating a prototype of the software and testing it in real educational settings. Adjustments and improvements are made based on test results.

Stage 4: Implementation and Monitoring — full-scale implementation of the software and regular evaluation of its effectiveness. New iterations are carried out based on collected data.

The proposed system of principles can serve as a theoretical and practical foundation for designing and implementing educational software that develops 21st century skills in





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academic lyceums. These principles are closely interrelated, and their comprehensive application contributes to enhancing the effectiveness of educational software.

Future research should focus on empirical validation of the proposed principles, evaluation of their effectiveness across various academic lyceums, and exploration of integration possibilities with artificial intelligence technologies.

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