IMPROVING THE METHODOLOGY FOR DEVELOPING DESIGN-ENGINEERING COMPETENCE OF FUTURE ENGINEERS THROUGH AUTOMATED DIGITAL SOFTWARE

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Abstract. This article examines the pedagogical and technological foundations for developing the design-engineering competence of future mechanical engineering specialists through automated digital software. It analyzes the necessity of integrating CAD/CAM/CAE systems into engineering education, the relevance of qualification requirements for the "Mechanical Engineering Technology, Equipment and Automation" field, and the structural characteristics of design-engineering competence as part of professional competence. figures, and a formalized competence-development function.

Keywords: automated digital software, CAD/CAM/CAE, engineering education, design-engineering competence, professional skills development, digital methodology.

Introduction. Rapid technological progress in Industry 4.0 and widespread digital transformation demand that future engineers possess strong design-engineering competencies. Modern enterprises increasingly rely on automated digital tools—including CAD (Computer-Aided Design), CAM (Computer-Aided Manufacturing), CAE (Computer-Aided Engineering), PLM (Product Lifecycle Management), and simulation platforms—to accelerate production cycles, reduce design errors, enhance product quality, and improve decision-making accuracy [1].

The Need for Automated Digital Software in Engineering Education. Automated digital software (ADS) supports all stages of the engineering workflow —concept design, modeling, simulation, verification, and documentation. The integration of ADS into educational practice is essential for several reasons:

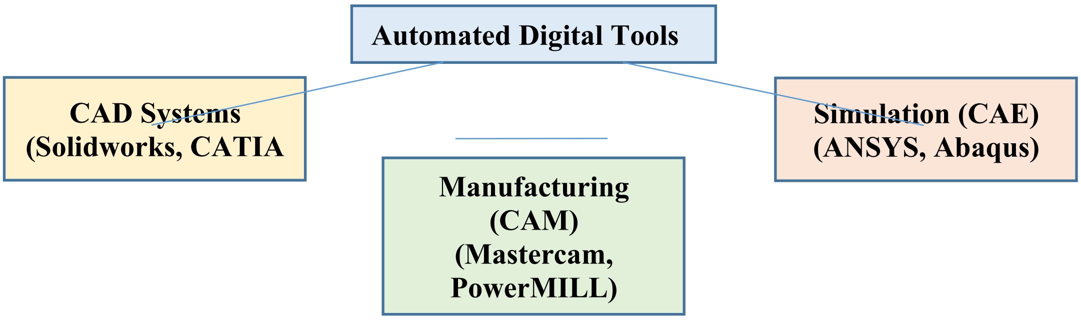

Figure 1. Role of Automated Digital Software (Conceptual Diagram)

Key pedagogical advantages:

- Enhances visualization of complex engineering objects
- Develops spatial thinking and 3D-modeling skills
- Increases accuracy and reduces human-based design errors
- Allows students to experience real industrial workflows

Table 1

Comparison of Traditional and Automated Approaches in Engineering Education

Criteria	Traditional Method	Automated Digital Method
Design speed	Low	Very high
Error detection	Manual, time-consuming	Automated, intelligent
Visualization	2D drawings	Realistic 3D/AR/VR
Integration with industry	Weak	Strong and seamless
Required competence level	Medium	High (digital literacy + engineering)

Competence-Development Function

To mathematically describe the competence development process, the following simplified function is proposed:

$$C_{dev}=f\left(D_s,P_t,S_m,A_i\right)$$

where: D_s – digital software proficiency;

P_t – project based training intensity;

S_m – simulation and modeling skills;

A_i – academic-industrial integration.

Competence increases when these our parametres grow harmoniously.

Qualification Requirements and Their Role in Developing Design-Engineering Competence. The curriculum of the "Mechanical Engineering Technology, Equipment and Automation" program emphasizes:

- Product design and modeling
- Engineering graphics
- Machine components and mechanisms
- Production automation
- Manufacturing process simulation
- Mechatronics and robotics
- Digital engineering technologies
- PLC Programming and Industrial Automation Control Systems
- Robotic Systems Design and Kinematics
- Product Lifecycle Management (PLM)

Design-engineering competence (DEC) represents a complex, multidimensional construct that forms one of the core elements of the professional competence of future engineers. This competence reflects the graduate's ability to independently design, model, analyze, optimize, and justify engineering solutions using modern digital tools and methodological approaches. In essence, DEC ensures that the future mechanical engineer is capable not only of understanding theoretical principles but also of transforming these principles into practical, innovative, and technically sound product designs [2,3].

From a structural point of view, design-engineering competence incorporates several interrelated components. The **cognitive component** includes the student's theoretical knowledge of machine design, engineering materials, engineering graphics, and digital modeling principles [4]. It enables the learner to understand the fundamental laws of mechanics, design logic, engineering analysis, and the technological structure of machine elements. This knowledge base forms the foundation upon which practical engineering decisions are built [5].

Moreover, the cognitive component ensures that students can **interpret engineering documentation**, understand **state and international standards**, and apply **calculation methodologies** necessary for solving complex design problems. Mastery of these theoretical foundations allows learners to effectively integrate scientific principles into practice, foresee potential design errors, and select optimal structural and technological solutions.

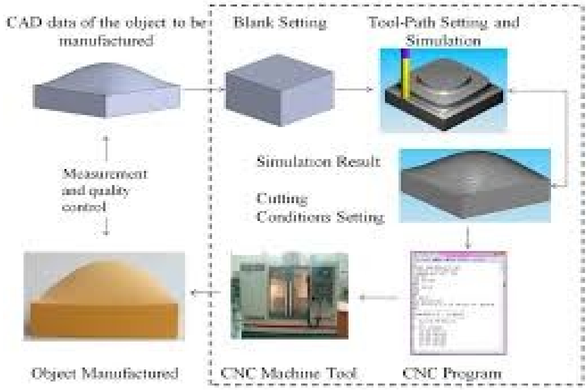 	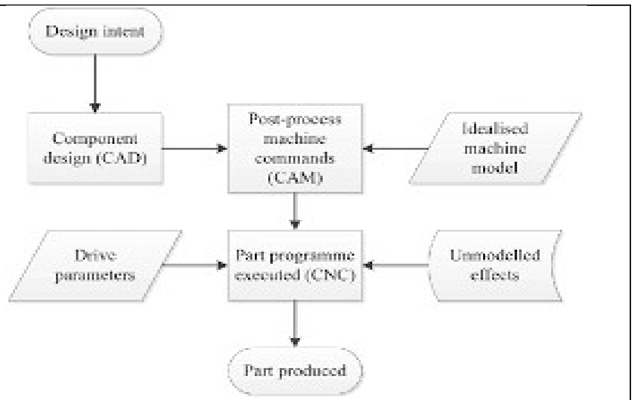
a) CAD–CAM–CNC Workflow and Error Sources in Digital Manufacturing	**b) Integrated CAD–CAM–CNC Manufacturing Process with Simulation and Quality Control**

Figure a. CAD–CAM–CNC Workflow and Error Sources in Digital Manufacturing. This diagram illustrates the overall digital manufacturing workflow starting from the *design intent* and ending with the *produced part*. The process begins with **Component Design (CAD)**, where the geometry and technical specifications of the part are created. This digital model is then converted into **post-processed machine commands through CAM software**, which generates toolpaths based on an *idealized machine model*.

Figure b. Integrated CAD–CAM–CNC Manufacturing Process with Simulation and Quality Control. This figure shows a detailed sequence of how a 3D model is transformed from a digital concept into a manufactured physical object. The process starts with **CAD data of the object to be manufactured**, where geometry is defined. A raw material block (**blank**) is prepared, followed by **tool-path setting and simulation** using CAM software.

The **creativity and innovation component** reflects the student's ability to generate new engineering ideas, propose unconventional design solutions, and apply modern technological trends in product development. It stimulates innovative thinking, enhances design originality, and supports the integration of advanced engineering approaches such as additive manufacturing, digital twins, generative design, and Industry 4.0 technologies [7,8].

Finally, the **professional–personal component** integrates qualities such as responsibility, accuracy, teamwork ability, engineering ethics, digital culture, and self-development skills. These attributes ensure that a future engineer can work effectively in multidisciplinary teams, communicate clearly, follow engineering standards, and demonstrate professional behavior that meets industry expectations [9].

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