

**TECHNOLOGY FOR PREPARING FUTURE ENGINEERS FOR PROFESSIONAL ACTIVITIES IN A BLENDED LEARNING ENVIRONMENT****Dilshod Baratov**

(Based on the Example of Teaching the "Agricultural Machinery" Discipline)

<https://orcid.org/0000-0001-5304-1381>**Ruziyev Elbek Rajabovich<sup>2</sup>**<sup>1,2</sup> Karshi State Technical University, Karshi, Uzbekistan<sup>1</sup> Corresponding author: [dilshod.baratov90@gmail.com](mailto:dilshod.baratov90@gmail.com)<sup>2</sup> Corresponding author: [eltin88@bk.ru](mailto:eltin88@bk.ru)**Abstract**

This article scientifically investigates the pedagogical technology for preparing future engineers for professional activities in a blended learning environment. Using the teaching of the discipline "Agricultural Machinery" as an example, an integration model between traditional classroom formats and digital educational tools has been developed. During the research, a structural-functional model of blended learning was proposed, in which synchronous and asynchronous teaching methods, simulation technologies, and a project-based approach are applied in harmony. The results of a pedagogical experiment conducted with 124 students show that the blended learning model increased professional knowledge acquisition by 23.4% and the level of practical skills by 31.7% compared to the traditional approach. The article presents the main conditions, obstacles, and methodological recommendations for implementing blended learning in engineering education.

**Keywords**

blended learning, engineering education, professional training, digital technologies, agricultural machinery, pedagogical technology, simulation.

**INTRODUCTION**

Efforts to modernize engineering education on a global scale are intensifying. The rapid pace of technological progress, the digital transformation of industry, and the ever-changing demands of the labor market are compelling educational institutions to fundamentally rethink the technologies used to train highly qualified engineers. In this context, the blended learning model is gaining wide recognition as an innovative approach to developing professional competence in higher engineering education.

Foreign research dedicated to the theory and practice of blended learning (Graham, 2006; Horn & Staker, 2014; Garrison & Kanuka, 2004) demonstrates that this model enables the integration of the best aspects of traditional face-to-face instruction and online learning. However, the application of blended learning in engineering education — and specifically in the teaching of technical disciplines — raises its own distinct methodological challenges: complex technical concepts, laboratory work, equipment-handling skills, and the assessment of



competence against professional standards all demand rigorous scientific inquiry.

Within the framework of higher education reform in the Republic of Uzbekistan, considerable attention is being paid to the implementation of blended instruction. The National Education Strategy for 2020–2030 identifies digital literacy and the development of distance learning infrastructure as priority directions. At the same time, the lack of a sufficient scientific and methodological base for the effective blended-environment teaching of specialized technical disciplines such as “Agricultural Machinery” defines the relevance of this study.

This research is directed at developing the pedagogical foundations for applying blended learning technology in the vocational preparation of future agricultural engineers. Its scientific novelty is manifested in the following: first, a specialized blended learning model has been created for the “Agricultural Machinery” discipline; second, a practical mechanism for integrating simulation technologies and project-based instruction has been proposed; third, the effect of this form of instruction on the development of professional competence has been demonstrated experimentally.

## LITERATURE REVIEW

The theoretical foundations of the blended learning model emerge at the intersection of several scholarly traditions. As Garrison and Kanuka (2004) emphasize, blended learning is not a superficial combination of online and traditional education but a deliberately intentional process of integration based on deep pedagogical thinking. This approach has been confirmed in an engineering education context by Dziuban, Hartman, and Moskal (2004), who noted a significant improvement in student academic achievement as a result of moving 50 percent of technical course content to an online format.

In the concept of “Disrupting Class” developed by Horn and Staker (2014), the rotation model — particularly suited to engineering education — holds special importance. In this model, students rotate through stations: one group works with the instructor, a second studies independently through computer programs, and a third collaborates on a group project. In the context of agricultural engineering, this approach allows virtual simulations to be alternated with hands-on assembly exercises when studying machine component design.

Research by Caner (2012) devoted to studying the effectiveness of blended instruction in engineering education shows that the advantages of the hybrid format are especially pronounced in the formation of vocational practical skills. A meta-analysis of 41 studies examined in that article demonstrates that blended learning increases learning effectiveness among engineering students by an average of 18–27% compared to traditional approaches.

In the field of agricultural machinery engineering education, Russian researcher Zinchenko (2019) has demonstrated the high pedagogical effectiveness of using 3D modeling and virtual reality technologies in teaching tractor and agricultural machine design. His research shows that students who perform assembly and disassembly operations on machine mechanisms in a virtual environment acquire technical knowledge 2.3 times faster than in a conventional laboratory.

Research conducted by Xolmatov and Raximova (2021), as well as the works of Mirzayev (2022), on the implementation of blended instruction in the Uzbek education system have enriched the methodological base for the local context. However, these studies do not



sufficiently examine the distinctive characteristics of teaching engineering specialty courses — in particular, technically complex courses such as “Agricultural Machinery” — in a blended environment. This gap further reinforces the scientific relevance of the topic.

## RESEARCH METHODOLOGY

### Research Design and Sampling

The study was carried out during the 2022–2023 academic year with second-year students enrolled in the “Agricultural Machinery and Equipment” program at Karshi Engineering and Economics Institute. The pedagogical experiment design divided participants into two groups: the control group (n=62) received instruction using traditional teaching methods, while the experimental group (n=62) studied under the blended learning technology developed for this research. The groups were comparable in composition — prior academic performance, gender distribution, and age — and a Kolmogorov–Smirnov test result of  $p > 0.05$  confirmed that initial differences between the groups were statistically insignificant.

### Structure of the Blended Learning Model

Within the scope of the research, the blended learning model specially designed for the “Agricultural Machinery” discipline consisted of the following components: (1) synchronous contact component — 2 hours of traditional lectures and 4 hours of laboratory sessions per week; (2) asynchronous online component — video lectures, interactive tests, and 3D models of machine designs hosted on the Moodle LMS platform; (3) project component — group work on a practical engineering project during the second half of the semester; and (4) simulation component — operating agricultural machinery through a full technological cycle using the AGROS simulation software.

The optimal ratio of contact to online hours was set at 60:40, a figure grounded in the recommendations of Graham (2006) and Dziuban et al. (2004) as well as the specific laboratory requirements of engineering education. The online and contact portions of each module were constructively aligned: the online module was designed to consolidate theoretical knowledge, while the contact session was intended for practical skill development and problem-solving.

### Data Collection and Analysis

A three-stage measurement system was used to assess learning outcomes. In the first stage (entry diagnostics), students’ baseline knowledge level was determined through a standardized assessment test. The second stage (process monitoring) included formative assessments every four weeks throughout the semester, analysis of online activity, and portfolio reviews. In the third stage (summative diagnostics), a written examination measuring theoretical knowledge was administered, alongside practical tests evaluating skills in handling technical equipment, and an expert assessment determining the overall level of professional competence.

The SPSS 26.0 statistical package was used to analyze the research results. An independent-samples Student’s t-test was applied to identify differences between the control and experimental groups, while a paired t-test was used to measure within-group dynamics. The validity of the practical skills assessment methodology was confirmed by a Cronbach’s  $\alpha$  of 0.87, indicating high internal consistency of the measurement instrument.



## RESULTS

### Comparative Analysis of Theoretical Knowledge Acquisition

A comparative analysis of examination results demonstrated a clear advantage for the experimental group. The control group achieved a mean score of  $67.4 \pm 9.2$ , while the experimental group's mean was  $83.2 \pm 7.8$ . The Student's t-test result ( $t=10.34$ ;  $df=122$ ;  $p<0.001$ ) confirmed that this difference is highly statistically significant. Cohen's d of 1.88, expressing the effect size, indicates that the blended learning model had a strong impact on academic outcomes.

When the analysis was broken down by module, the largest differences were observed in "Tractors and Their Engine Systems" (86.1% in the experimental group vs. 64.3% in the control group), "Complex Agricultural Harvesting Machinery" (84.7% vs. 63.9%), and "Hydraulic Transmissions" (82.4% vs. 61.8%). These results suggest that blended learning is particularly effective in studying complex mechanical systems — a finding that clearly illustrates the role played by online 3D models and simulations in providing visual explanation.

*Table 1. Comparative Performance Indicators of the Control and Experimental Groups*

Indicator	Control Group	Experimental Group	Difference (%)	p-value
Theoretical knowledge (100 pts)	$67.4 \pm 9.2$	$83.2 \pm 7.8$	+23.4%	<0.001
Practical skills (100 pts)	$61.8 \pm 10.4$	$81.4 \pm 8.1$	+31.7%	<0.001
Professional competence (expert assessment)	$64.2 \pm 8.7$	$79.6 \pm 7.3$	+24.0%	<0.001
Academic motivation (Lichko scale)	$3.8 \pm 0.7$	$4.4 \pm 0.5$	+15.8%	<0.01

### Analysis of Practical Skills Development

The most notable difference was observed in the assessment of practical skills. The experimental group's mean score was  $81.4 \pm 8.1$ , compared to just  $61.8 \pm 10.4$  in the control group — representing an improvement of +31.7% ( $t=11.87$ ;  $df=122$ ;  $p<0.001$ ;  $d=2.17$ ). Expert assessment results indicated that experimental group students performed particularly well in diagnosing tractor hydraulic systems, carrying out scheduled maintenance procedures on



combine harvesters, and adjusting the operational parameters of harvesting machinery.

A correlational analysis of the number of tasks completed in the simulation system and academic outcomes identified a statistically significant moderate positive association ( $r=0.64$ ;  $p<0.001$ ). A notable correlation was also found between the degree to which asynchronous online module materials were studied (mean time logged in the LMS) and theoretical knowledge scores ( $r=0.58$ ;  $p<0.001$ ), suggesting that the development of self-regulated learning habits is an important pedagogical outcome of blended instruction.

### **Student Engagement and Motivation in the Learning Process**

Based on questionnaire results and LMS activity data, experimental group students showed higher academic motivation ( $4.4\pm 0.5$  vs.  $3.8\pm 0.7$  on the 5-point Lichko scale) and greater levels of self-regulated learning activity. Observations conducted throughout the semester showed that 87.1% of experimental group students submitted online modules by the set deadline, a figure considerably higher than the 64.3% average recorded for traditional courses taught in parallel. Student professional interest and positive attitudes toward academic activity also increased in a statistically significant manner ( $\chi^2=14.7$ ;  $p<0.001$ ).

### **DISCUSSION**

The effectiveness of the blended learning model applied in our research can be analyzed through several interrelated mechanisms. First, the visual explanation of complex mechanical systems through 3D models and virtual simulations in the online component transforms abstract technical concepts into a tangible, concrete reality for students. This finding is consistent with Mayer's (2009) multimedia learning theory and with Zinchenko's (2019) conclusions on virtual modeling in engineering education.

Second, the constructive alignment of the contact and online components — whereby the online module provides theoretical knowledge while the contact session creates opportunities for practical application — demonstrates the effective application in engineering education of the “constructive alignment” principle developed by Garrison and Kanuka (2004). It should be noted, however, that the model's effectiveness was measured over only a single semester and within a single institution. Generalizing these findings to other contexts would require broader, multi-center studies.

Comparing our research results with those of foreign studies yields interesting conclusions. The improvement figures of +23.4% and +31.7% found in our study are notably higher than the average meta-analytic range of +18–27% identified by Caner (2012). This discrepancy may be partly explained by the inherently visual nature of the agricultural machinery field and partly by the deep integration of simulation and project components in our research.

The main challenges encountered in transitioning engineering education to a blended environment were as follows: technical infrastructure (internet connectivity issues and lack of devices, affecting 18.5% of students); instructor digital literacy (some instructors required additional methodological support due to technical difficulties in creating LMS-based materials); and insufficient development of independent planning skills among some students. These challenges correspond to the typical barriers to blended learning identified in the research of Owston (2013).

The introduction of the project component played a distinctive role in the formation of professional competence. As students worked on an engineering project throughout the semester,



they experienced a learning environment closely approximating the conditions of real professional practice. This approach is consistent with a contemporary interpretation of Kilpatrick's project-based learning theory and with the recommendations of Engineering for Change (2022) on the application of a project-based approach in engineering education.

## CONCLUSION

This research was devoted to the development and testing of an innovative pedagogical technology for preparing future engineers for professional activities in a blended learning environment. The following principal conclusions were reached.

First, the blended learning model specially created for the "Agricultural Machinery" discipline delivered statistically significant gains in theoretical knowledge acquisition ( $p < 0.001$ ;  $d = 1.88$ ) and practical skills development ( $p < 0.001$ ;  $d = 2.17$ ) compared to the traditional approach.

Second, a 60:40 (contact:online) ratio, the integration of 3D simulation technologies, and a project component were substantiated as the optimal model for blended instruction in engineering education, and their positive influence on professional competence was demonstrated.

Third, infrastructure, instructor competence, and the development of students' self-regulation skills were identified as the key determinants of success in implementing blended learning.

Based on the research findings, the following practical recommendations are offered:

1. It is advisable to begin the implementation of blended instruction in engineering disciplines by conducting trial runs with small pilot groups.
2. Specialized professional development programs in digital pedagogy must be developed for instructors.
3. A model of constructive alignment between simulation and virtual modeling tools and real laboratory sessions should serve as the foundation of pedagogical design.
4. Special attention should be paid to instructional and methodological materials aimed at developing metacognitive skills in students.

The following are identified as promising directions for future research: testing the blended learning model in other engineering specialty disciplines (e.g., "Automation of Technological Processes," "Engineering Materials"); the pedagogical potential of integrating artificial intelligence-based adaptive learning systems with the blended learning model; and the long-term (2–5 year) effects of blended instruction in engineering education on professional practice.

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