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# ENHANCING ICT COMPETENCE OF FUTURE COMPUTER SCIENCE TEACHERS THROUGH CLUSTER-BASED EDUCATION MODELS

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**Abstract**

This study explores the development of information-technological training for future computer science teachers within an educational cluster environment. The research was conducted over three years at Chirchik State Pedagogical University, Termez State University, and the Jizzakh branch of the National University of Uzbekistan, involving 444 students. The study employed a pedagogical experiment based on the "Methods of Teaching Informatics" program, integrating game-based learning, exercises, and virtual simulation videos. Findings indicate that these methods significantly enhanced students' information-technological competencies, particularly in applying software tools and problem-solving. The training model fostered independent decision-making, critical analysis, and the development of design and research skills essential for professional growth. The impact of this approach lies in its capacity to modernize teacher education, aligning it with the demands of a digital learning environment.

Keywords: Computer science, Education, ICT, Teacher, Uzbekistan.

## 1. Introduction

The rapid advancement of information and communication technologies (ICT) demands that future computer science teachers acquire advanced professional skills in applying these tools effectively in education [1-3]. Many reports regarding ICT have been well-documented [4-8]. High-quality ICT training supports dynamic changes in pedagogy, including new forms, methods, and didactic principles [9]. Teachers must plan lessons, select content, and design educational processes using digital tools [10]. Developing competencies in ICT not only enables teachers to manage information but also to foster digital learning environments [11].

The purpose of this study is to develop and evaluate an information-technological training model for future computer science teachers within an educational cluster, focusing on improving their digital competencies and instructional effectiveness. The novelty of this research lies in applying a cluster-based model that integrates innovative teaching methods, such as game-based learning, simulations, and peer collaboration, to enhance both technological and pedagogical skills in a structured, collaborative educational environment.

## 2. Literature Review

The criteria presented in Table 1 allow for the organization of a procedure for assessing the information and technological readiness of students. Criteria include Cognitive, Motivational-value, Active, and Creative.

**Table 1. Criteria for evaluating the information and technological training of future computer science teachers.**

| Criterions | Indicators of the development of information and technological training |
|---|---|
| **Cognitive** | knows the symbols used in modelling.<br>knows the software used for modelling.<br>knows the functional capabilities of programming languages and mathematical software packages, as well as ways to develop independent new ones; |
| **Motivational value** | build real objects in accordance with the established goals of professional activity.<br>a specialist in modelling and design methods in the professional field.<br>it has the instrumental capabilities of programming languages and applied mathematical software packages for solving professional problem problems. |
| **Active** | is interested in formalizing, modelling and designing problematic professional issues in the professional and practical sphere.<br>is interested in using programming languages and applied mathematical software packages in the process of modelling and design; |
| **Creative** | conducts a critical analysis of the object of modelling.<br>assesses their level of mastery in the modelling process, project work, and programming.<br>assesses the adequacy of the model.<br>languages and applied mathematical software packages |

Figure 1 illustrates the structure of the information-educational cluster, where diverse educational institutions collaborate, sharing goals and resources to enhance educational quality and competitiveness within a region [1, 11]. This model supports problem-based learning, teacher training, and specialist development. This

relates to the strategies on how to improve higher institution education, as reported elsewhere [12-16].

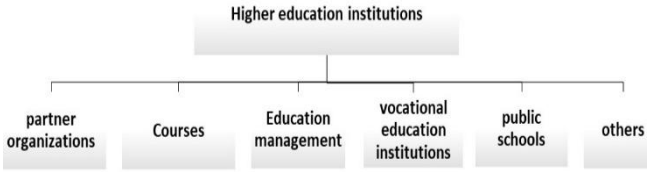


**Fig. 1. Information and educational cluster.**

Figure 2 presents the competency system shaping the technological training of future computer science teachers. This includes cognitive, motivational, active, and creative components necessary for effective ICT integration in pedagogy [2, 17]. Figure 3 shows the professional training components as an integral personality system, combining knowledge, skills, and personal qualities. These elements adapt continuously to technological advancements and evolving educational demands [17]. The integration of modern teaching methods like Flipped Classroom, Remote Labs, and Peer-to-Peer Teaching has been shown to enhance ICT competencies and learning outcomes in various studies [17, 18]. This underscores the necessity of innovative methodologies within cluster environments to prepare future computer science teachers effectively.

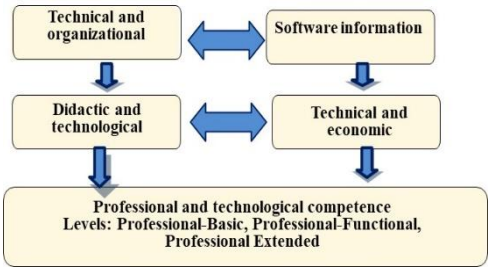


**Fig. 2. The system of competencies that shape the professional and technological training of future computer science teachers.**


**Fig. 3. Components representing professional training with an integral state of personality**.

## 3. Method

This study employed a pedagogical experiment over three years across three universities in Uzbekistan: Chirchik State Pedagogical University, Termez State University, and the Jizzakh branch of the National University of Uzbekistan. Detailed information regarding this method is explained elsewhere [19]. A total of 444 future computer science teachers participated, with 221 in the experimental group and 223 in the control group.

The experimental design focused on developing students' information-technological competencies through innovative teaching methods, including game-based learning, exercise-based methods, virtual simulation videos, Flipped Classroom, Projects, Remote Labs, Peer-to-Peer Teaching, and Discovery Problems. These methods were selected to enhance problem-solving, modelling, and research skills. The evaluation criteria included cognitive, motivational, active, and creative indicators related to ICT competencies, assessed at the beginning and end of the experiment. This approach ensured a comprehensive measurement of growth in technological and pedagogical abilities within a cluster-based educational environment.

## 4. Results and Discussion

Tables 2 3 present the results of the pedagogical experimental work conducted over three years at Chirchik State Pedagogical University, Termez State University, and the Jizzakh Branch of the National University of Uzbekistan. A total of 444 students participated-221 in the experimental group and 223 in the control group. We analysed statistics to get a better understanding of the results. Detailed information on how to analyse using statistical analysis is reported elsewhere [20-22].

In the experimental group, the percentage of students demonstrating a high level of information and technological training increased from 22.7% at the start to 35.7% at the end of the experiment.

The medium level rose from 40.2% to 46.2%, while the low level decreased significantly from 37.1% to 18.1%. In comparison, the control group showed minimal improvement: the high-level category increased slightly from 21.1% to 23.3%, and the low level decreased modestly from 41.2% to 36.8%.

These findings confirm the effectiveness of the cluster-based educational approach and the integration of interactive methods like Flipped Classroom, Projects, and Remote Labs, as emphasized in prior studies [10, 17]. The problem-based learning structure and the use of simulation tools enhanced students' readiness and practical skills in ICT, aligning with the competencies.

Furthermore, the collaborative cluster model promoted resource sharing and methodological consistency across institutions, contributing to improved student outcomes [11, 23]. This advancement highlights the critical role of educational clusters in fostering ICT competencies among future computer science teachers and supports previous findings that interactive and context-based learning strategies significantly enhance professional preparedness.

This study adds new information regarding ICT, as reported elsewhere [24-28].

**Table 2. The results of pedagogical experimental work: experiment.**

| The level of development of information and technological training | Experiment group | | | |
|---|---|---|---|---|
| | At the beginning of the experiment 228 students (%) | | End of experiment 221 students (%) | |
| High | 52 | 22.7 | 79 | 35.7 |
| Medium | 92 | 40.2 | 102 | 46.2 |
| Lower | 85 | 37.1 | 40 | 18.1 |

**Table 3. The results of pedagogical experimental work: control.**

| The level of development of information and technological training | Control group | | | |
|---|---|---|---|---|
| | At the beginning of the experiment 228 students (%) | | End of experiment 223 students (%) | |
| High | 48 | 21.1 | 52 | 23.3 |
| Medium | 86 | 37.7 | 89 | 39.9 |
| Lower | 94 | 41.2 | 82 | 36.8 |

## 5. Conclusion

The study demonstrated that the cluster-based educational model, combined with interactive teaching methods, effectively enhances the information and technological training of future computer science teachers. The experimental group showed significant improvement in ICT competence compared to the control group, confirming the success of integrating problem-based learning, simulation tools, and collaborative environments. This approach ensures that future teachers are better prepared to utilize modern technologies in their professional practice, contributing to a more dynamic and effective educational system.

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