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ENHANCING STUDENTS' READINESS FOR THE TIMSS INTERNATIONAL ASSESSMENT THROUGH DIGITAL TECHNOLOGIES AND VIRTUAL SIMULATIONS IN CHEMISTRY EDUCATION

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Abstract. This article explores the role of digital technologies and virtual simulations in improving students' readiness for the TIMSS international assessment in chemistry education. The study focuses on the effectiveness of integrating ICT tools, such as virtual laboratories and simulation-based tasks, into the learning process. An experimental study was conducted with 8th-grade students, comparing traditional teaching methods with ICT-supported instruction. The findings show that students who engaged in simulation-based learning demonstrated better understanding of chemical processes, improved analytical thinking, and higher problem-solving skills. The results indicate that the use of digital technologies significantly enhances students' functional literacy and supports their preparation for international assessment programs like TIMSS.

Keywords. TIMSS, digital technologies, virtual simulations, ICT in education, chemistry education, functional literacy, virtual laboratories, simulation-based learning

Introduction. The rapid development of society, the emergence of the information age enriched by advanced technologies, as well as increasing global competition and scientific and technological progress have intensified the demand for highly qualified specialists. In this context, modern professionals are expected not only to possess solid theoretical knowledge but also to demonstrate the ability to critically evaluate complex situations, make informed decisions, and exhibit both logical and creative thinking skills. Consequently, educational practices based solely on traditional teaching methods are no longer sufficient to meet these demands, thereby necessitating the adoption of innovative pedagogical approaches. The integration of contemporary information and communication technologies (ICT) into the educational process plays a crucial role in fostering students' intellectual, physical, and personal development, while also enhancing key competencies such as analytical thinking, problem-solving, and decision-making. Furthermore, the application of ICT tools transforms the learning environment into a more interactive, engaging, and learner-centered process, promoting students' autonomy, creativity, and active participation in knowledge construction.

At present, most general education schools are equipped with modern computers, multimedia tools, and telecommunication technologies. This creates opportunities not only for the modernization of the educational process but also for the effective preparation of students for international assessment programs. In particular, the TIMSS international study evaluates not only students' knowledge in mathematics and science but also their functional literacy, logical reasoning, and ability to analyze information.

Therefore, in order to successfully complete simulation-based tasks and computer-based tests in the TIMSS format, it is essential that students possess an adequate level of ICT literacy. When organizing lessons using modern ICT tools, teachers focus on key components such as lesson objectives, strategies for achieving them, instructional materials and their presentation methods, teaching approaches, types of tasks, questions for discussion and debate, as well as the interactive organization of student collaboration. Such an approach not only enhances the

effectiveness of the learning process but also promotes the development of students' independent thinking, decision-making based on experimental evidence, and analytical skills. From this perspective, the widespread integration of modern information and communication technologies in schools is of strategic importance for improving students' readiness for TIMSS and other international assessment programs. Furthermore, continuous professional development of teachers and the enhancement of their competencies in applying interactive and simulation-based methods remain essential pedagogical priorities.

Methodology. The aim of this study is to determine the effectiveness of students' ICT literacy and their ability to perform simulation-based tasks in the process of preparing for the TIMSS international assessment. The research was conducted in general secondary schools among 8th-grade students within the context of chemistry education.

During the study, an analysis of existing scientific literature related to international assessment programs, ICT literacy, simulation-based tasks, and the integration of virtual laboratories into the educational process was carried out. In addition, students' experience in using virtual laboratories, their interest in interactive methods, and their level of motivation were examined. In the practical phase of the research, experimental and control groups were formed. Students in the experimental group studied chemistry using ICT tools and simulation-based tasks. The instructional process included the use of virtual laboratories, interactive models, animations, multimedia presentations, and online simulation platforms. Simulation-based tasks enabled students to model various chemical processes, such as electrolysis, reactions of acidic and basic solutions, gas formation processes, and changes in solution concentration within a virtual environment.

Furthermore, students developed skills in analyzing results and visualizing reaction rates, product yields, and interrelationships through graphs and diagrams. Tasks were completed both individually and collaboratively, fostering independent thinking, experimental design skills, and group discussion. The control group, in contrast, was taught using traditional methods, where tasks were limited to paper-based exercises and standard laboratory work. A comparison of the results between the experimental and control groups made it possible to evaluate the effectiveness of ICT-based tasks. Students' ICT literacy and their ability to perform simulation-based tasks were assessed through diagnostic tests, virtual activities, and questionnaires. Teachers were provided with guidelines for using virtual laboratories and interactive platforms, and classroom environments were equipped with computers, projectors, interactive whiteboards, and online modeling tools.

Thus, the proposed methodology enabled the evaluation of students' functional literacy in chemistry, their skills in performing simulation-based tasks, and their readiness for TIMSS-format assessments. The practical findings confirmed the effectiveness of the interactive approach, highlighting the importance of ICT-based tasks in developing students' logical thinking, experimental design, and data analysis skills.

Virtual Laboratories and Simulation Exercises

- Conducting experiments in a virtual environment, such as electrolysis, reactions of acidic and basic solutions, and gas formation processes.
- Analyzing reaction rates, product yields, and concentration changes using graphs and diagrams.
- Modeling different scenarios and comparing results by modifying experimental conditions.

Interactive Tests and Problem-Solving Tasks

- Completing electronic tests and simulation-based tasks in the TIMSS format.
- Interpreting unexpected results, identifying errors, and developing logically grounded solutions.
- Assessing students' abilities in rapid thinking, analysis, and decision-making through test-based activities.

Graphical and Animation-Based Modeling Tasks

- Studying reaction kinetics, matter transformation, and atomic–molecular interactions using animated models.
- Visualizing and analyzing experimental results.
- Providing students with opportunities to present their findings in graphical formats.

Results and Discussion. The results of the study indicate that the use of modern information and communication technologies in chemistry lessons significantly improved students' knowledge levels and functional literacy. Students in the experimental group, who were taught using virtual laboratories and simulation-based tasks, demonstrated higher performance compared to those in the control group. The learners showed better outcomes in analyzing chemical processes, interpreting experimental results, and working with graphical data. Moreover, they effectively demonstrated independent decision-making skills and the ability to draw scientific conclusions in problem-based situations.

Simulation-based tasks supported by ICT proved to be an effective tool for developing students' logical thinking, analytical approaches, and experimental skills, while also enhancing their readiness for international assessment programs.

Conclusion. In conclusion, the effective integration of ICT into the educational process, when organized in accordance with the above-mentioned requirements, significantly contributes to improving the quality of teaching and learning. The implementation of these recommendations in pedagogical practice can lead to high educational outcomes and contribute to the comprehensive development and academic preparedness of the younger generation.

In the national education system, the effective use of ICT in teaching school subjects remains a highly relevant task. Information technologies serve as a universal educational tool, providing opportunities not only for the formation of students' knowledge, skills, and competencies but also for the development of their personal qualities and the satisfaction of their cognitive interests.

Pedagogical and psychological studies emphasize that ICT has a significant impact on the development of students' theoretical, creative, and reflective thinking. The visualization of events and processes in students' memory enriches learning materials and facilitates their deeper scientific understanding.

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