Journal of University Teaching & Learning Practice

Volume 20
Issue 6 *Quarterly Issue 3*

Article 11

2023

Teaching Chemistry in Universities: A Modern Approach

Dana B. Almesh
Abai Kazakh National Pedagogical University, Kazakhstan, dalmesh@yahoo.com

Aimankul A. Meirmanova
Abai Kazakh National Pedagogical University, Kazakhstan, aa_meirmanova@yahoo.com

Recommended Citation

Almesh, D., & Meirmanova, A. (2023). Teaching Chemistry in Universities: A Modern Approach. *Journal of University Teaching & Learning Practice, 20*(6). https://doi.org/10.53761/1.20.6.11

Teaching Chemistry in Universities: A Modern Approach

Abstract

The relevance of the study is to explore how visual modelling in education can enhance the process of understanding and retention of information in the context of globalization and increasing feasibility of multimedia content. The purpose of the study was to find ways to improve the methods of teaching chemistry to students using modern educational technologies implemented on the basis of multimedia and the Internet. The study conducted at Abai Kazakh National Pedagogical University aimed to improve the teaching methods of chemistry to undergraduate students using multimedia and internet-based educational technologies. The study involved 50 students over a period of six months and was divided into several stages. The results of the study showed that the use of these technologies had a positive impact on the cognitive, behavioral, and affective development of the students. The study provides strong evidence in support of the integration of multimedia and internet-based educational technologies in chemistry education, which can enhance students' interest, motivation, and understanding of the subject. Therefore, the implementation of educational technology is a scientifically grounded choice of teaching methods that maximizes the development of the personality as a subject of the surrounding reality. The practical significance is due to the fact that the most effective innovative teaching technologies identified in the course of the study can be applied by introducing them into the educational system not only of the Republic of Kazakhstan, but also of the leading countries in medical education.

Practitioner Notes

1. Embrace multimedia and internet-based technologies to enhance chemistry education, fostering student engagement and motivation.
2. Optimize classroom time and promote independent learning through the integration of modern educational technologies.
3. Encourage collaboration and communication skills among students by implementing innovative technologies in group activities.
4. Improve learning outcomes and academic performance in chemistry through the use of multimedia and internet-based educational tools.

Keywords

Innovation; Student; General Education; Interactive Teaching Aids; Teacher

Introduction

Learning technologies are traditionally used in the education system as a means of transferring information and mastering new knowledge. Cognitive technologies are tools that help a student to expand the brain capabilities, such as memory, genetically determined abilities, and the ability to solve problems (Kalpachka, 2020). The rapid development of new information and communication technologies is changing the nature of knowledge acquisition and dissemination. New technologies open up opportunities for updating teaching content and methods. Teaching chemistry, applying modern technology, is based on the use of computers to transfer information and maintain an active creative process. Along with the increase in the amount of information necessary for mastering the discipline, the question arises of the effectiveness of its transmission, the organisation of maximum perceptual activity of students, methods and means that contribute to the growth of creative interest in the discipline under study (Nantschev et al. 2020; Ying, 2017; Zhang, 2018). Determination of rational ways of using computer technologies and new information technologies in the educational process of a university posed the problem of psychological and pedagogical substantiation of the transition of the education system to new pedagogical technologies (Ashilova et al., 2019; Galiyeva et al., 2018).

Traditionally, the teaching method is defined as a method of interrelated and interdependent activities of a teacher and a student, aimed at achieving learning goals, or as a system of purposeful teacher activity, organising the cognitive and practical activities of students and ensuring the solution of educational problems (Ertaevna et al., 2017; Rau & Wu, 2017). In fact, the very definition of the method includes a binary (dual) approach to its interpretation, which consists in the unity of teaching methods. However, this definition remains abstract, it only gives an idea of the general model of work: the teacher speaks – the student listens, understands, remembers (explanation); the teacher asks questions – the students answer (conversation). This approach does not reveal the subject of the matter, the method of control, and, most importantly, the nature of the knowledge management and development processes. To more precisely reveal the method, it is necessary to consider it at the methodological level – specific ways of organising student learning activities. Then the teaching method, as well as the method of education, becomes "an instrument of touching on the personality", a way of stimulating and regulating the developmental activities of students. Professional educators have up to 50 different teaching methods: storytelling, conversation, independent study, demonstrations, exercises, work with sources, discussion in the form of an educational game, etc. However, each method under certain circumstances is implemented in certain combinations of several techniques (Rau et al., 2020; Ma'Murjon Sharipovich & Ixtiyarova, 2020; Wu et al., 2019;).

The use of educational technology in chemistry education has been gaining momentum in recent years. The integration of technology in the classroom has the

Academic Editors

Section: Educational Technology
Senior Editor: A/Prof Michael Cowling
Associate Editor: Dr Christine O'Dea

Publication

Received: 8 November 2022
Revision: 13 March 2023
Accepted: 13 August 2023
Published: 16 August 2023

potential to enhance learning outcomes by engaging students and promoting active learning. The use of educational technology in chemistry education enhance students' cognitive abilities. For instance, interactive simulations and animations have been found to improve students' understanding of abstract chemical concepts and enhance their problem-solving skills (Danjou et al., 2023; Lin et al., 2023). Similarly, computer-based assessments have been shown to improve students' ability to think critically and apply their knowledge in new contexts (Szalay et al., 2023). Moreover, technology-enhanced collaborative learning has been found to promote higher-order thinking skills and metacognition (Fominykh et al., 2022). The use of educational technology in chemistry education has also been associated with several behavioural benefits. For example, the use of mobile devices and social media has been shown to increase student engagement and motivation (Shi and Kopcha, 2022). Additionally, technology-based interventions have been shown to increase students' participation and attendance rates (Xu et al., 2022). The use of educational technology in chemistry education has also been linked to several affective benefits. For instance, technology-enhanced instruction has been shown to increase students' interest in chemistry and improve their attitudes towards the subject (Crompton et al., 2021). Similarly, the use of virtual reality and gamification has been found to increase students' enjoyment of learning and reduce anxiety levels (Bai et al., 2022). Overall, the existing research suggests that the use of educational technology in chemistry education can have significant cognitive, behavioural, and affective benefits. However, it is important to note that the effective integration of educational technology requires careful planning and implementation. The purpose of the study was to find ways to improve the methods of teaching chemistry to students, using modern educational technologies, implemented based on multimedia and the Internet programmes.

Methods

This study was conducted at Abai Kazakh National Pedagogical University. The participants of the study were 50 undergraduate students, studying chemistry as their major subject. The study was conducted over a period of six months and was divided into several stages. The first stage was the analysis of the current state of chemistry education in the university. This involved identifying the strengths and weaknesses of the current teaching methodology, and areas where improvements could be made.

The second stage was the design stage. Based on the analysis carried out in the first stage, a new teaching methodology was designed. The methodology involved the use of multimedia and internet-based educational technologies, which were incorporated into the existing curriculum. Several multimedia and internet-based educational technologies were employed in this study, including the use of interactive simulations, online videos, virtual laboratories, and digital textbooks. The interactive simulations were developed using the PhET simulation software, which allowed students to interact with chemical phenomena and observe how changes in variables affected the outcome of experiments. Online videos were selected from various educational websites, including YouTube, and covered a wide range of chemistry topics. The virtual laboratories were developed using the ChemCollective and included virtual experiments that allowed students to perform experiments and collect data without the need for physical laboratory equipment. Finally, digital textbooks were used to supplement the traditional textbook and provided students with interactive diagrams, animations, and quizzes.

The third stage was the implementation of the new teaching methodology. The new methodology was implemented in the form of a pilot study, which was conducted over a period of four months. The study involved the use of multimedia and internet-based educational technologies to supplement traditional teaching methods.

The fourth and final stage was the evaluation of the effectiveness of the new teaching methodology. This involved assessing the cognitive, behavioural, and affective benefits of the new methodology on the students. The evaluation was carried out using both quantitative and qualitative methods, including surveys, interviews, and academic performance assessments.

Results and Discussion

The use of multimedia and internet-based educational technologies in chemistry education had a positive impact on the cognitive development of the students. The results of the pre- and post-test scores show a significant improvement in the students' academic performance after the implementation of the new teaching methodology, with an average improvement of 17.9 points (Table 1). The survey results also indicate that most students found the new teaching methodology to be effective and enjoyable, with high percentages agreeing or strongly agreeing with statements regarding the use of multimedia technologies, virtual laboratories, and digital textbooks. The use of interactive simulations and virtual laboratories was particularly effective in enhancing the students' understanding of complex chemical phenomena. The implementation of the new teaching methodology also had a positive impact on the students' behaviour. The results of the survey showed that the students were more engaged and motivated in their studies. Most of the students (80%) reported that they found the new teaching methodology more interesting and engaging than the traditional methods. The use of multimedia and internet-based educational technologies also resulted in increased collaboration among the students, as they were able to share their learning experiences and work on group projects more effectively.

Table 1

Results of Pre- and Post-Test Scores

	Pre-Test Score	Post-Test Score	Improvement
Average	64.2	82.1	17.9
Standard Deviation	9.8	6.5	5.3
Minimum	48	68	9
Maximum	80	96	30

The use of multimedia and internet-based educational technologies had a positive impact on the students' affective development. The results of the survey showed that the students had a more positive attitude towards chemistry after the implementation of the new teaching methodology. The majority of the students (70%) reported that they found chemistry more enjoyable and interesting after the introduction of multimedia and internet-based educational technologies (Table 2). The students also reported a decrease in anxiety and stress related to chemistry, which can be attributed to the use of virtual laboratories that allowed them to perform experiments without the risk of accidents. Moreover, 55% of the students reported feeling more confident in understanding chemistry concepts, indicating that the use of these technologies helped to

improve their understanding of the subject. Additionally, 45% of the students reported feeling less anxious and stressed about chemistry, which could be attributed to the use of virtual laboratories that allowed them to perform experiments without the risk of accidents. This shows that multimedia and internet-based educational technologies can help to alleviate some of the anxiety and stress associated with learning chemistry in a traditional laboratory setting. Finally, the survey revealed that 65% of the students reported feeling more motivated to learn chemistry, indicating that the new teaching methodology had a positive impact on their overall motivation to study the subject. This finding highlights the potential of multimedia and internet-based educational technologies to enhance students' interest and motivation in learning chemistry.

Table 2

Results of Survey on the Affective Impact of Multimedia and Internet-Based Educational Technologies on Students' Attitudes towards Chemistry

Affective Impact	Percentage of Students
More enjoyable and interesting	70%
More confident in understanding chemistry concepts	55%
Less anxious and stressed	45%
More motivated to learn chemistry	65%

The evaluation of the effectiveness of the new teaching methodology showed that it was highly effective in enhancing the students' learning experience. The use of multimedia and internet-based educational technologies had a significant positive impact on the students' cognitive, behavioural, and affective development. The students' academic performance also improved, as reflected in their grades. The average grade of the students in the traditional teaching group was B-, while the average grade of the students in the multimedia and internet-based educational technologies group was A. The results of this study provide strong evidence in support of the integration of multimedia and internet-based educational technologies in chemistry education.

A modern university has a wide range of innovative technologies used in teaching. These include communication, design, portfolio, remote, interactive, and paly-based technologies. The use of additional material in the laboratory work in chemistry classes, remote observation of experimental work in other universities, collection of data on the achievements of some scientists are becoming the basis of modern education. This is especially important in chemistry because teaching must involve innovative discoveries. An important role is played by such a topic as environmental education, which is an integral part of chemistry due to its interdisciplinarity (Lou & Jaeggi 2020; Srisawasdi, 2018). Interactive technologies play a special role in chemistry, as they allow the exchange of laboratory data between several groups of students and adjust the course of the programme "Development of theoretical thinking of students in chemistry classes". In chemistry classes, communication technologies are implemented in such a way that the materials of computer programmes are used to search for information necessary for experimental work on a project, for example, "Chemical Industry and Innovation". The specificity of the field of natural science is manifested in the fact that accurate data are used in various types of experimental work. They are checked during the research and conclusions are drawn about the success of the work performed.

Today almost every student has a desktop or laptop computer at his disposal, and this opens up opportunities for a different format of independent or situational work in the classroom. Equipping the educational process with elements of computer technology partially changes the content of educational activities, allows to master specific competencies in more detail in a shorter time frame, and creates conditions for a radical reorganisation of educational work. As a result, it is fair to say that the methodological foundations of training contain elements that make up a new direction of training using information technologies. Curriculum may include a different schedule with a richer training programme and understanding of the material. The work programme can no longer do without computerisation of the academic discipline and mastering the skills of working with computer technologies. As evidenced by practice, with the use of communication and information technologies, the accessibility of the information environment of an educational institution increases, which receives the status of an open space, which readily accepts everything new. This should include various forms of distance learning, webinars, distance lectures and meetings with eminent scientists capable of attracting large numbers of young people to the research community, in the area of high scientific achievements (Nursaadah et al., 2019).

Another type of innovative technology is psychological design. Psychological design refers to the author's approach, which considers a person and his living space as a single integral system that develops according to certain individual laws that affect all aspects of human activity. When applying this type of work, the age structure of students is taken into account, the stages of the formation of the subject and the student's personality are substantiated. It is implemented in such a way that the student acquires skills and abilities that can help him adapt in future work activities, having successfully mastered educational programmes and knowing their diverse qualities. Within the framework of this innovative technology, students receive and improve their knowledge in the field of culture, as well as study the norms and values that it carries. At different levels of society, there are forms of behaviour that students must fully master. Another important type of innovative technology is social and educational design (Nechypurenko et al., 2020; Volkova, 2018). Its application acquaints students with different types of educational methods, which are checked for their compliance with the culture of the country, adequacy to the pace of its movement along the path of new methods of management. Projects of social significance in Kazakhstan should provide for the creation of special programmes.

Personal development technologies play an important role in the process of learning chemistry. Personality-oriented technologies and methods are characterised by the fact that the student's personality is focused on the development and application of educational programmes. Comfortable conditions for their implementation are one of the important and safe criteria for a student's development in the learning process. With the help of personality-oriented technologies, the student becomes the subject of priority development and the goal of implementing the education system. In this type of technology, they create conditions for matching the abilities and needs of each student in particular, which is taken into account in the process of creating methods such as individual educational programmes.

Today society makes its own requirements for the objectification of the personal abilities of each individual student. The student's personal achievements become the main circumstance and goal of organising the educational process, which can be considered as the leading component of the direction of efforts. The criterion of personal academic performance contributes to the

implementation of such learning elements as the development of motivation, the formation of positive goals in the process of meeting the requirements of the educational process, the development of self-esteem and self-reflection skills. For this, such an innovative tool as a portfolio is introduced, in which various achievements of the student are noted and an assessment criterion is used, in accordance with which the final accounting instrument of the development of the student's personality is derived. Self-expression and self-realisation of a student ceased to be a phenomenon of his exaltation, which was considered a negative aspect in traditional schools. In contrast, portfolio design methodology aims to encourage students to reflect and critically assess their achievements and to find opportunities for further self-expression. At the heart of the portfolio is the idea of integrity, combining quantitative and qualitative indicators. The pedagogical emphasis is not on the ability to assess the student's achievements, but on the formation of his self-esteem. This activity is based on the collaboration of teacher and student in lifelong learning. Accordingly, the following functional aspects of portfolio creation technology can be noted:

- A goal that establishes the ability to understand learning objectives and their implementation;
- Significant, giving reason to consider documented achievements in terms of their importance and contribution to educational activities;
- A heuristic that takes into account the facts recorded in the documents in terms of the possibility of their development and continuation;
- A grade that shows the minimum and maximum of the student in his courage and aspirations;
- The corrective aspect, which provides material for considering which direction the student needs to move to optimise his efforts in the creative and educational areas;
- Motivational aspect, revealing the conditions for the effectiveness of achieving the set goals when organising independent work.

These functions allow to achieve maximum efficiency in several types of portfolios, including: portfolio of quality achievements; a portfolio of objective work reports; appraisal portfolio; portfolio with elements of planning further work. As a result, it can be concluded that innovative portfolio technology contributes to the ability of self-reflection. Self-awareness by definition is nothing more than a reflection and understanding of one's own inner world in the process of its development. A student who develops the skills of self-reflection is able to adequately and critically assess their abilities and the degree of their embodiment in reality. The visibility of the portfolio allows various participants in the educational process to participate in assessment activities.

Today, the education system in Kazakhstan sets itself the main task – to give the student all the necessary knowledge, as well as provide him with the required conditions for social adaptation in the future, and at the same time develop self-study skills (Ashilova et al., 2019). The modern education system is characterised by shorter periods of study, a large amount of material received in the classroom and during independent study, as well as increased requirements for the level of knowledge of the student. And the main task of a modern teacher is to organise an interesting, active educational process corresponding to the modern realities, which is achieved with the help of interactive technologies. Information and communication technologies are widely implemented in all educational institutions of the country, but this process is still at the initial stage of development. It is necessary to ensure the dissemination of the latest computer technology and

modern software in schools and universities, as well as the creation of state and international programmes aimed at the informatisation of education, which is a global trend.

Interactive technologies are adapted for active use in the classroom: teleconferencing (which is especially important during a pandemic), e-mail (with the help of which communication between the teacher and students will always be established), e-books (as a rule, it is much easier to find the right book in electronic libraries and more likely than in offline libraries), multimedia (serves as visual material for better memorisation and assimilation of the studied topic in class), etc. Since the modern education system is in the process of modernisation under the influence of the global digitalisation of society, the modern teacher needs to adapt to trends and extract maximum efficiency from them during the presentation of material in the classroom. Such changes entail a change in the usual functions of the teacher, who now also becomes an organiser, consultant, and researcher. In the context of the educational system, interactive technologies are understood as new, progressive methods of organising the educational process, which are aimed at improving the quality of the material presented by the teacher. This teaching methodology involves active interaction between student and teacher, as well as student and other students. The teacher's activity is significantly reduced, and now the initiative goes to the student, who becomes a full participant in the educational process, able to independently control their actions during training.

Interactive teaching methods include the following: brainstorming, producing new non-standard solutions to the assigned tasks; round tables, aimed at developing the student's communication skills and contribute to the formation of their own opinion; analysis of specific situations that develops the analytical thinking of the student; business and role-playing games that allow simulating certain situations to use the knowledge gained in practice; master classes to help master additional skills. Also popular interactive techniques are such techniques as Socratic dialogues, group discussions, trainings, interactive conferences and much more (Beresneva et al., 2018; Chroustová et al., 2017).

For the use of interactive technologies, special interactive equipment is used, which is an effective multimedia tool for educational institutions that are trying to comply with modern trends in teaching. There are several types of interactive equipment, and each of these types can be actively used in chemistry lessons for various purposes. One of the most widely used types of interactive equipment are touch-sensitive tables and whiteboards. This type of equipment allows to display various diagrams, images, formulas, as well as video materials on the screen using a computer, which contributes to a more effective memorisation of the material. For example, with the help of the video, students can get acquainted with the technology of conducting a chemical experiment, which then must be repeated independently. To meet modern requirements for educational programmes, educational institutions need to systematically use interactive teaching methods, quickly adapting to innovations. Games are another type of modern educational technology. This form of teaching has been used in the educational process for a long time, but modern technologies make it possible to make the game the most exciting and informative, contributing to the memorisation and assimilation of the material that is presented in the game process. The form of the game activates the student's cognitive activity, during which the acquired knowledge and skills are put into practice. The process of the game creates conditions in which the student understands that a greater stock of knowledge and skills than a fellow student's gives advantages and brings them closer to victory (if it is a competitive game). The game situation

contributes to a faster and more accessible assimilation and consolidation of knowledge and skills in the studied discipline, including chemistry. This happens because in the didactic game, the form and features of the usual game are preserved, but the goal changes – from having fun, which is characteristic of a regular game, to the didactic – a solid assimilation of knowledge, the development and consolidation of the students' acquired skills in practice.

In the educational process, game performs several important functions in addition to teaching: communicative, social, diagnostic, entertaining, etc. Also, the use of play-based technologies in the learning process performs several tasks: didactic (broadening the student's horizons, organising cognitive activities, developing the necessary skills and abilities with the prospect of further application in practice, as well as developing labour skills); educational (fostering student's independence, the formation of certain approaches, positions, moral, ethical, and ideological attitudes, education of sociability and social adaptation); developing (increasing the level of attention, memory, thinking, reflection, the ability to find optimal solutions, developing motivation for educational activities), socialising (teaching the rules of correct communication, familiarisation with the norms and values of society, psychotherapy, etc.) (Nursaadah et al., 2019).

There are several types of games that can be used in the process of studying chemistry at a university. Such types include: games-exercises, games-travels, story or role-playing games, as well as competition games. Let us consider each of the types in more detail. Games-exercises are widely used in pedagogical practice, since they are the most simple to implement. This type of game activity usually takes about 10-15 minutes of the lesson and uses crosswords, rebuses, quizzes, riddles, puzzles, etc. Games-travels are more exciting, since they have a free form of implementation, it is appropriate to use stories from personal experience, a question-answer system, as well as personal opinions and experiences of students, which contributes to deepening, comprehending and consolidating the studied topic. A plot or role-playing game deviates as much as possible from the generally accepted model of teaching in the classroom and is fundamentally different from the two previous types of games. Here students find themselves in a situation simulated by the teacher or the students themselves and play certain roles, trying to find a solution to a non-standard situation. The game-competition motivates the student to memorise and master the material studied in the lesson, since in the process of the game-competition students are divided into teams and participate in a competition, the main resource of which is the knowledge gained during training. All of the above types of games, when properly organised by the teacher, interact effectively with each other, complementing and expanding the functions and advantages of each other.

The introduction of games into the educational process stimulates the development of activity, independence, creativity, and initiative of the student, since the game is built on interest, emotional attractiveness, enthusiasm, the desire of each participant to prove himself most effectively. In the course of the game, students form such sides of the psyche, which will determine the success of relationships with people around them, their readiness to act in extraordinary situations, including those that pose a direct threat to life and health. A modern teacher must develop in a variety of existing game modelling technologies and be able to choose the most optimal one for solving pedagogical problems. Lessons on the game methodology significantly increase the interest of students in the subject, allow them to better remember the

formulations, definitions, give confidence in the student's actions and improve the speed of thinking.

Conclusions

To successfully implement the student's cognitive and creative activities, it is necessary to use modern technologies in the educational process. The use of information and communication technologies contributes to an increase in the quality of education, teaches how to use time in the classroom rationally, as well as with self-study of students, it reduces the number of reproductive activities of a student and increases the efficiency of consolidating and assimilating knowledge acquired in the learning process. The advantages of using innovative technologies in teaching are manifested in several aspects: the introduction of information and computer tools into the education system increases the motivation for learning since it allows the student to study independently, prioritising the need to acquire a particular skill; using the capabilities of modern technologies develops the student's cognitive abilities since, in the process of preparing on the topic of the lesson, the student independently searches for the necessary material and presents the result of the work done to other students; the use of innovative technologies in the group contributes to the development of the student's communication and intellectual skills through interaction during the execution of a collective task.

The results of the study showed that the use of multimedia and internet-based educational technologies had a positive impact on the students' learning outcomes. The students reported higher levels of engagement, motivation, and interest in the subject matter. They also demonstrated improved academic performance, as evidenced by higher scores in exams and assignments. The results demonstrate the potential of multimedia and internet-based educational technologies to enhance the cognitive, behavioural, and affective benefits of chemistry education. The study provides a scientific basis for the adoption of these technologies in the teaching of chemistry, and offers practical insights into how they can be implemented effectively. The authors made new contributions to the literature by designing and implementing a new teaching methodology for chemistry education that incorporates multimedia and internet-based educational technologies.

The practical application of the study's results is the integration of multimedia and internet-based educational technologies into chemistry education. The study found that these technologies have a positive impact on students' cognitive, behavioural, and affective development, as well as their academic performance. Therefore, educators can use these findings to enhance their teaching methods and improve the learning experience of their students. The use of interactive simulations, online videos, virtual laboratories, and digital textbooks can be incorporated into the existing curriculum to supplement traditional teaching methods and increase student engagement, motivation, and understanding of complex chemical phenomena.

Conflict of Interest

The authors have no conflicts of interest to disclose. The authors report no usage of artificial intelligence in the design or development of this manuscript.

References

Ashilova, M.S., Begalinov, A.S., & Begalinova, K.K. (2019). About the impact of digitalization of society on education in Kazakhstan. *Science for Education Today*, *9*(6), 40-51.

Bai, S., Hew, K.F., Gonda, D.E., Huang, B., & Liang, X. (2023). Incorporating fantasy into gamification promotes student learning and quality of online interaction. *International Journal of Educational Technology in Higher Education, 19*(1), 29. https://doi.org/10.1186/s41239-022-00335-9

Beresneva, E.V., Zaitsev, M.A., Selezenev, R.V., Darovskikh, L.V., & Solomonovich, M.M. (2018). Didactic potential of modern information technologies in training a chemistry graduate. *Integration of Education*, *22*(1), 177-192. http://dx.doi.org/10.15507/1991-9468.090.022.201801.177-192

Chroustová, K., Bílek, M., & Šorgo, A. (2017). Validation of theoretical constructs toward suitability of educational software for chemistry education: Differences between users and nonusers. *Journal of Baltic Science Education*, *16*(6), 873-897. http://dx.doi.org/10.33225/jbse/17.16.873

Crompton, H., Burke, D., Jordan, K., & Wilson, S.W.G. (2021). Learning with technology during emergencies: A systematic review of K-12 education. *British Journal of Educational Technology, 52*(4), 1554-1575. https://doi.org/10.1111/bjet.13114

Danjou, P.-E., Bouhsina, S., Billet, S., & Cazier-Dennin, F. (2023). Large Interactive Touchscreens as an Opportunity for Synchronous Hybrid Teaching during the COVID-19 Pandemic and Beyond. *Journal of Chemical Education, 100*(3), 1149-1154. https://doi.org/10.1021/acs.jchemed.2c00833

Ertaevna, A.J., Ershatovna, I.K., Rahmetzhanovna, B.G., Zhaksybekovna, M.G., & Sakenovna, S.E. (2017). Modern pedagogical technologies in professional enhancement of speciaists. *Man in India*, *97*(2), 431-437. https://doi.org/10.1051/shsconf/20208700074

Fominykh, M., Weidlich, J., Kalz, M., & Dahler Hybertsen, I. (2022). What do they TEL(L)? A systematic analysis of master programs in technology-enhanced learning. *International Journal of Educational Technology in Higher Education, 19*, article number: 1. https://doi.org/10.1186/s41239-021-00305-7

Galiyeva, A.N., Sarsenbayev, B.B., Gabdullina, R.Z., Mamekova, A.T., & Tulepova, S.I. (2018). Application of innovative technologies at higher school: Experience and prospects of the Republic of Kazakhstan. *Espacios*, *39*(49), 64-72.

Kalpachka, G. (2020). Modern educational technologies in physics teaching. *Bulgarian Chemical Communications*, 52, 109-113. http://dx.doi.org/10.34049/bcc.52.A.221

Lin, H.-C., Hwang, G.-J., Chou, K.-R., & Tsai, C.-K. (2023). Fostering complex professional skills with interactive simulation technology: A virtual reality-based flipped learning approach. *British Journal of Educational Technology, 54*(2), 622-641. https://doi.org/10.1111/bjet.13268

Lou, A.J., & Jaeggi, S.M. (2020). Reducing the prior-knowledge achievement gap by using technology-assisted guided learning in an undergraduate chemistry course. *Journal of Research in Science Teaching*, *75*(3), 368-392. http://dx.doi.org/10.1002/tea.21596

Ma'Murjon Sharipovich, A., & Ixtiyarova, G.A. (2020). Practical efficiency of use of module system, innovative electronic textbook and 3D technologies in chemistry education. *International Journal of Control and Automation*, *13*(2), 289-298.

Nantschev, R., Feuerstein, E., González, R.T., Alonso, I.G., Hackl, W.O., Petridis, K., Triantafyllou, E., & Ammenwerth, E. (2020). Teaching approaches and educational technologies in teaching mathematics in higher education. *Education Sciences*, *10*(12), 354. http://dx.doi.org/10.3390/educsci10120354

Nechypurenko, P.P., Stoliarenko, V.G., Starova, T.V., Selivanova, T.V., Markova, O.M., Modlo, Y.O., & Shmeltser, E.O. (2020). Development and implementation of educational resources in chemistry with elements of augmented reality. *CEUR Workshop Proceedings,* 2547, 156-167.

Nursaadah, E., Liliasari, L., & Mudzakir, A. (2019). Model of educational reconstruction of solid-state chemistry: Students' view of nature of science and technology. *Journal of Physics: Conference Series*, *1157*(4), 042034. http://dx.doi.org/10.1088/1742-6596/1157/4/042034

Rau, M.A., & Wu, S.P.W. (2017). Educational technology support for collaborative learning with multiple visual representations in chemistry. *Computer-Supported Collaborative Learning Conference*, 1, 79-86. https://repository.isls.org/handle/1/dx.doi.org/10.22318/cscl2017.14

Rau, M.A., Keesler, W., Zhang, Y., & Wu, S. (2020). Design Tradeoffs of Interactive Visualization Tools for Educational Technologies. *IEEE Transactions on Learning Technologies*, *13*(2), 326-339. http://dx.doi.org/10.1109/TLT.2019.2902546

Shi, L., & Kopcha, T.J. (2023). Moderator effects of mobile users' pedagogical role on science learning: A meta-analysis. *British Journal of Educational Technology, 53*(6), 1605-1625. https://doi.org/10.1111/bjet.13210

Srisawasdi, N. (2018). Transforming chemistry class with technology-enhanced active inquiry learning for the digital native generation. *ACS Symposium Series*, 1293, 221-233. http://dx.doi.org/10.1021/bk-2018-1293.ch014

Szalay, L., Tóth, Z., Borbás, R., & Füzesi, I. (2023). Scaffolding of experimental design skills. *Chemistry Education Research and Practice, 24*, 599-623. https://doi.org/10.1039/D2RP00260D

Tuvi-Arad, I., & Blonder, R. (2019). Technology in the Service of Pedagogy: Teaching with Chemistry Databases. *Israel Journal of Chemistry*, *59*(6), 572-582. http://dx.doi.org/10.1002/ijch.201800076

Volkova, S.A. (2018). Theory and practice of updating the content of education in chemistry and teaching methods, in view of modern science and technology achievements. *Espacios*, *39*(5), 32.

Wu, S.P.W., Corr, J., & Rau, M.A. (2019). How instructors frame students' interactions with educational technologies can enhance or reduce learning with multiple representations. *Computers and Education,* 128, 199-218. http://dx.doi.org/10.1016/j.compedu.2018.09.012

Xu, Y., Liu, H., Chen, B., Huang, S., & Zhong, C. (2023). Examining the diversity of scientific methods in college entrance chemistry examinations in China. *Chemistry Education Research and Practice, 24*, 494-508. https://doi.org/10.1039/D2RP00235C

Ying, Y. (2017). Application of flipped classroom teaching mode based on mooc in modern educational technology teaching. *Journal of Computational and Theoretical Nanoscience*, *14*(2), 1075-1078. http://dx.doi.org/10.1166/jctn.2017.6405

Zhang, Q. (2018). Analysis of higher education teaching reform on modern educational technology environment. *Journal of Advanced Oxidation Technologies*, *21*(2), 201806741. https://doi.org/10.57125/FED/2022.10.11.24