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Yuliia Shaforost*
PhD in Chemistry, Associate Professor
Bohdan Khmelnytsky National University of Cherkasy
18031, 81 Shevchenka Blvd., Cherkasy, Ukraine
https://orcid.org/0000-0002-0002-2803

Valentyna Shpak
Doctor of Pedagogy, Professor
Bohdan Khmelnytsky National University of Cherkasy
18031, 81 Shevchenka Blvd., Cherkasy, Ukraine
https://orcid.org/0000-0003-0913-6150

Andrii Shaforost
Student
Bohdan Khmelnytsky National University of Cherkasy
18031, 81 Shevchenka Blvd., Cherkasy, Ukraine
https://orcid.org/0009-0003-3027-554X

Maker education as a means of implementing edutainment in the teaching of chemistry to upper secondary school pupils

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*Corresponding author (zdoryulia@ukr.net)

Abstract. In the contemporary context of educational development, the use of innovative pedagogical approaches aimed at increasing learners' motivation and fostering their research and creative activity has become particularly important. One of the most promising directions is the integration of edutainment and maker education. The aim of this study was to substantiate and experimentally verify the effectiveness of the maker education approach as a means of implementing edutainment in the process of teaching chemistry to Year 11 pupils. A combination of theoretical and empirical methods was employed, including the analysis and synthesis of scientific and pedagogical literature, pedagogical modelling, classroom observation, questionnaires, interviews, and a pedagogical experiment. The results of the pedagogical experiment demonstrated that, at the initial stage, both groups were characterised predominantly by medium and low levels of cognitive activity. During the formative stage, pupils in the experimental class completed maker education tasks and mini-projects involving the construction of experimental models and the conduct of investigations. The implementation of these activities contributed to increased cognitive engagement and to the development of creativity and independence. Comparative analysis of the results obtained at the initial and final stages revealed a significant improvement in the level of cognitive activity among pupils in the experimental class: the proportion of pupils demonstrating a high level increased from 10% to 43%, while the proportion of those with a low level decreased from 43% to 9%. The findings confirmed the effectiveness of maker education tasks as a means of enhancing learning activity and increasing motivation to study chemistry. The practical value of the study lay in the development of a methodological model for organising maker education activities and a system of maker education tasks for chemistry teaching, which were tested by student teachers during their teaching practice

Keywords: motivation; cognitive activity; design; experimentation; STEM education

INTRODUCTION

Contemporary educational development is characterised by the active implementation of innovative pedagogical approaches aimed at increasing learners' motivation and fostering the development of their research and creative skills. One such approach is edutainment, which combines educational activities with elements of interactivity, creativity, and practical engagement. Its use contributes to the creation of a learning environment in which the process of acquiring knowledge becomes more engaging, emotionally rich, and closely connected with real-life situations. Unlike traditional forms of instruction, edutainment focuses on the active participation of learners in cognitive activities through game-based technologies, project work, multimedia tools, experimentation, and collaborative interaction. Such an approach not only enhances interest in academic subjects but also promotes the development of critical thinking, communication skills, the ability to search for information independently, and its practical application. Edutainment is particularly relevant in the context of the digitalisation of education and the need to develop competences required for successful professional and social integration in contemporary society. In this regard, investigating the possibilities of integrating edutainment into the educational process represents an important direction for improving teaching methods and enhancing the quality of education.

T. Kucher (2021) analysed the principles and best practices for designing digital learning environments based on game technologies. The study synthesised approaches to the creation of game-based learning environments and demonstrated that their effectiveness depends on the combination of pedagogical design, interactivity, and the active involvement of learners. C. Steinkuehler (2023) examined games as social platforms for learning and interaction. The author emphasised that gaming environments facilitate community building, promote communication, and support informal learning through participant interaction. L.C. Brandl & A. Schrader (2024), in their systematic review, investigated the role of serious games in transforming education within the framework of Education 4.0. Their findings indicated that the use of serious games contributes to increased learner motivation and engagement. The authors stressed that the effectiveness of game-based approaches depends on their integration into pedagogical design and alignment with educational objectives rather than merely the presence of entertainment elements. M. Li *et al.* (2023), in a meta-analysis, explored the effectiveness of gamification in education. They found that the use of game elements positively influences learners' motivation, engagement, and academic performance, although the degree of effectiveness depends largely on the quality of pedagogical design. J.J. Ramírez-Ruiz *et al.* (2024), in a systematic review, investigated the impact of gamification on learner engagement. Their results showed that the use of game elements contributes to increased academic, emotional, and behavioural engagement in the learning process.

Contemporary studies also highlight the importance of employing innovative educational technologies in the teaching of science subjects, particularly chemistry, since interactive digital tools, simulations, and virtual laboratories contribute to a deeper understanding of complex scientific concepts and the development of twenty-first-century competences. V. Honcharuk *et al.* (2025) analysed the current state of implementing innovative pedagogical technologies within the system of science education in Ukraine. Y. Feldman-Maggor *et al.* (2025) investigated the possibilities of using generative artificial intelligence in chemistry education within the framework of the TPACK approach. Their study examined the potential for integrating technological tools into the educational process and emphasised their role in supporting teachers' pedagogical and subject-specific knowledge. V. Kolodii *et al.* (2025) developed interactive virtual laboratories for distance learning in science subjects. Their research demonstrated that the use of such laboratories promotes the development of practical skills and enhances the effectiveness of learning and understanding educational content.

One of the promising areas for implementing the activity-based approach in education is maker education, which involves learning through the creation of one's own products, experimentation and practical activities. Q. Ou & X. Chen (2024) investigated the content and structure of maker education programmes, taking into account the capabilities of artificial intelligence. The authors analysed the characteristics of organising maker-oriented learning and highlighted its importance for the development of creativity, innovative thinking and practical skills among learners. Considerable attention is also paid to integrating the maker approach into the training of future teachers. In particular, the results of recent studies indicate that the use of maker practices in teacher training contributes to the development of future teachers' professional competence, their creativity and their readiness to apply innovative teaching methods in school practice, as demonstrated in the work of L.B. Calheiro & I.M. Greca (2025).

At the same time, some recent studies indicate that the maker approach has a positive impact on pupils' motivation to study science, fosters an interest in STEM careers and boosts their confidence in their own learning abilities. Researchers K. Chen *et al.* (2024) investigated the integration of maker activities into the teaching of science subjects in formal school settings. The quasi-experimental study found that such integration helps to improve pupils' scientific self-efficacy and supports their motivation and interest in STEM fields. According to a study by O.A. Sorochynska *et al.* (2022), the introduction of STREAM education incorporating elements of maker activities in pre-school settings contributes to the development of children's research skills, creativity and the formation of their scientific and natural science competences. The maker movement is actively developing worldwide as a component of STEM and STEAM education, creating conditions for the integration of science, technology, engineering, art and mathematics.

Despite the growing number of studies devoted to the use of edutainment and maker education in the teaching of natural science disciplines, the issue of applying the maker approach as a means of implementing edutainment in the methodological training of future chemistry teachers remains insufficiently explored. Thus, contemporary research confirms the effectiveness of game-based and maker approaches; however, the issue of their integration into the methodological training of chemistry teachers remains insufficiently explored. In particular, there is a lack of comprehensive studies aimed at combining maker activities with elements of edutainment in the context of chemistry teaching. The aim of the study was to theoretically substantiate and experimentally verify the effectiveness of the maker approach as a means of implementing edutainment in the study of chemistry by Year 11 pupils. Improvements in pupils' educational outcomes can be regarded as an indicator of the effectiveness of the methodological training of future chemistry teachers, as they reflect the effectiveness of the pedagogical technologies applied.

MATERIALS AND METHODS

The study was conducted at one of the secondary education institutions in Cherkasy between September 2024 and May 2025. The name of the school has not been disclosed in order to comply with confidentiality requirements and to protect the personal data of the study participants. A range of theoretical and empirical methods was employed during the study. A range of theoretical and empirical methods was employed during the study. The theoretical methods included the analysis, synthesis and generalisation of scientific and pedagogical sources on the topics of maker education, edutainment and chemistry teaching methodologies, as well as pedagogical modelling, which enabled the development of a system of maker tasks for chemistry lessons. The empirical methods included pedagogical observation, a questionnaire designed by the authors and a pedagogical experiment. The questionnaire for pupils was conducted offline at a general secondary school in Cherkasy during chemistry lessons. The survey was anonymous and voluntary. Pupils completed the questionnaires individually in written form. The questionnaire consisted of 10 closed-ended and semi-open-ended questions aimed at determining the level of cognitive activity, learning motivation, interest in the subject and awareness of the practical significance of chemistry.

The developed teaching materials were tested during the teaching placements of students specialising in 014 Secondary Education (Chemistry). Future teachers applied the developed maker tasks incorporating elements of edutainment whilst conducting chemistry lessons at the aforementioned school. The selection of topics from the school chemistry curriculum for implementing the maker approach was based on a combination of didactic and methodological criteria. The main selection criteria included: the possibility of organising practice-oriented activities involving the construction of models, conducting experiments and creating physical or functional objects; the availability of simple and safe materials suitable for use in a school laboratory or for home experiments; the presence of significant cross-curricular potential (STEM integration), in particular links to physics, biology and technology; the possibility of visualising and observing the results of activities, which is important for implementing the edutainment approach; and the practical relevance of the teaching material and its connection to pupils' everyday lives.

These criteria were selected in view of the nature of the maker approach and the specific characteristics of edutainment, as they ensure a combination of active creative engagement by pupils, the safety of lessons, cross-curricular integration and a high level of motivation in learning. In accordance with these criteria, topics related to the properties of solutions (electrical conductivity of solutions and electrolytes) and electrochemical processes (galvanic cells) were selected for the implementation of maker-based tasks. These topics from the Year 11 chemistry curriculum provide optimal conditions for organising pupils' research, project-based, and design activities, which correspond to the essence of the maker education approach and contribute to the implementation of edutainment. One of the general secondary education institutions in Cherkasy was selected for the pedagogical experiment and statistical analysis of the results, and control and experimental groups of pupils were formed on this basis.

The study involved 44 Year 11 pupils, of whom 23 formed the control group and 21 constituted the experimental group. In the control group, chemistry was taught using traditional instructional methods, whereas in the experimental group maker education tasks and mini-projects incorporating elements of edutainment were employed. The study was conducted in accordance with ethical principles governing research involving participants in the educational process. Pupils participated voluntarily, and verbal consent was obtained from both the pupils and their parents (legal guardians) prior to the commencement of the study. No personal data were collected or processed, and the results are presented in an aggregated form. The study adhered to the principles of academic integrity and ethical guidelines for conducting educational research (World Medical Association, 2013). The educational experiment consisted of three stages: the baseline stage, the formative stage and the control stage. The following criteria were identified to assess the level of pupils' cognitive activity: interest in the subject, engagement whilst completing learning tasks, independence in learning activities, participation in practical and research work, and the capacity for reflection. Assessment was carried out on the basis of questionnaire results, pedagogical observation and analysis of the completion of practical tasks.

A standardised assessment scale was used for the quantitative interpretation of the results: high level (75-100% manifestation of the specified indicators), medium level (40-74%), and low level (less than 40%). Pupils were assigned to the appropriate level based on a synthesis of the data obtained according to the specified criteria. Methods of quantitative and qualitative analysis were applied to process the results. In particular, to test the statistical significance of differences between the control and experimental groups, the χ^2 test (Pearson's chi-square) was used to compare the distribution of levels of cognitive activity between the groups at a significance level of $p < 0.05$. This made it possible to assess the effectiveness of using maker tasks as a means of implementing edutainment in the educational process.

RESULTS AND DISCUSSION

The effectiveness of the maker education approach as a means of implementing edutainment in chemistry teaching was examined through a pedagogical experiment comprising initial and formative stages. During the initial stage, the baseline levels of cognitive activity, learning motivation, and pupils' interest in studying chemistry were assessed. To achieve this, pupils were surveyed, classroom observations of their learning activities were conducted, and their performance in chemistry lessons was analysed. Analysis of the responses provided by pupils in the control class revealed an overall low level of cognitive activity. The majority of respondents (approximately 70%) indicated that chemistry lessons were interesting only occasionally, while 25% considered them uninteresting. Only 5% of pupils reported a sustained interest in the subject. More than half of the pupils did not associate chemical knowledge with everyday life: 48% only partially recognised the practical significance of chemistry, and 35% saw no application of chemistry in real-life situations.

With regard to participation in laboratory work, the majority of respondents (more than 60%) completed such activities only at the teacher's request, whereas only a small proportion demonstrated genuine enthusiasm. Furthermore, 80% of respondents stated that they never independently sought additional information related to chemistry. A considerable proportion of pupils assessed their own mastery of the material as low: 61% believed that they possessed only basic knowledge without deeper understanding, while 35% reported that they remembered very little of the material studied. At the same time, 43% of pupils expressed a potential interest in the use of practical or creative tasks in chemistry learning. Generalisation of the questionnaire findings made it possible to determine the levels of cognitive activity among pupils in the control class. As shown in Figure 1, low (47%) and medium (43%) levels of cognitive activity predominated, whereas only 10% of pupils demonstrated a high level. These findings indicate an insufficient level of learning motivation and interest in studying chemistry.

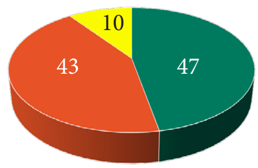

Figure 1. Levels of cognitive activity among pupils in the control class at the diagnostic stage of the experiment
Source: compiled by the authors

A similar trend was observed in the experimental class. Only 10% of pupils reported a sustained interest in chemistry, whereas 67% indicated that the lessons were interesting only occasionally, and 23% considered them uninteresting. In response to the question regarding the practical significance of chemistry, 52% of respondents stated that they sometimes reflect on its applications, 38% did not perceive any practical value in the subject, and only 10% provided specific examples of the use of chemical knowledge in everyday life. With regard to laboratory work, 57% of pupils carried it out only at the teacher's request, 33% participated when the experiments were interesting, and only 10% always worked with enthusiasm. Analysis of the responses also revealed a low level of learning motivation, with the majority of pupils (62%) indicating that receiving marks was the main incentive for studying. Based on the generalisation of the data obtained, the following levels of cognitive activity among pupils in the experimental class were identified: high – 10%; medium – 47%; low – 43%. The summarised results of the questionnaire survey conducted in the experimental class are presented in Figure 2. A comparative analysis of the questionnaire results from the control and experimental classes showed that the figures for both groups are similar. In both classes, medium and low levels of cognitive activity predominate, whilst the proportion of pupils with a high level of interest in the subject is negligible. The comparative questionnaire results are presented in Figure 3.

The data obtained indicated that both groups had similar initial levels of motivation and cognitive activity, which made them comparable for the purposes of the formative stage of the pedagogical experiment. In addition to the questionnaire survey, classroom observations of pupils' learning activities were conducted over the course of three lessons during the initial stage. The observations focused on the following criteria: activity during the explanation of new material; participation in laboratory experiments; collaboration within groups; independence in completing tasks; creativity in practical activities; and the ability to reflect on learning. Analysis of the findings revealed that pupils in both classes demonstrated predominantly moderate levels of learning activity. In the control class, a greater dependence on teacher assistance and a lower degree of creative initiative were observed. Pupils in the experimental class displayed slightly higher levels of group interaction and interest in laboratory work; however, these differences were not substantial. Thus, the results of the questionnaire survey and classroom observations demonstrated that medium and low levels of cognitive activity and creative skills predominated in both classes. Pupils showed a limited awareness of the practical significance of chemical knowledge and rarely demonstrated independent cognitive activity. At the same time, their positive attitude towards the teacher and their potential interest in practical and creative tasks created favourable conditions for the implementation of the maker education approach in chemistry teaching. These findings provided the basis for the formative stage of the pedagogical experiment, aimed at enhancing pupils' cognitive activity through maker education practices.

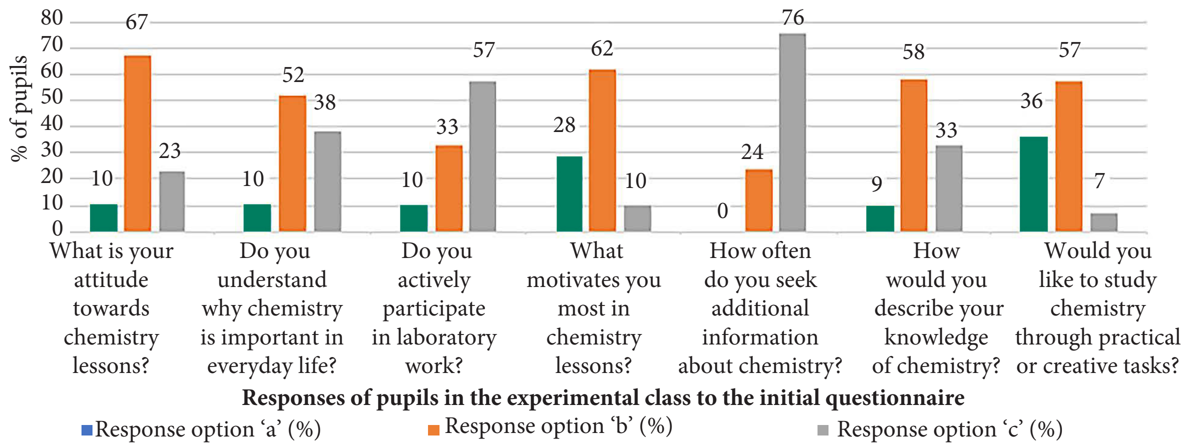

Figure 2. Results of the questionnaire survey of pupils in the experimental class
Source: compiled by the authors

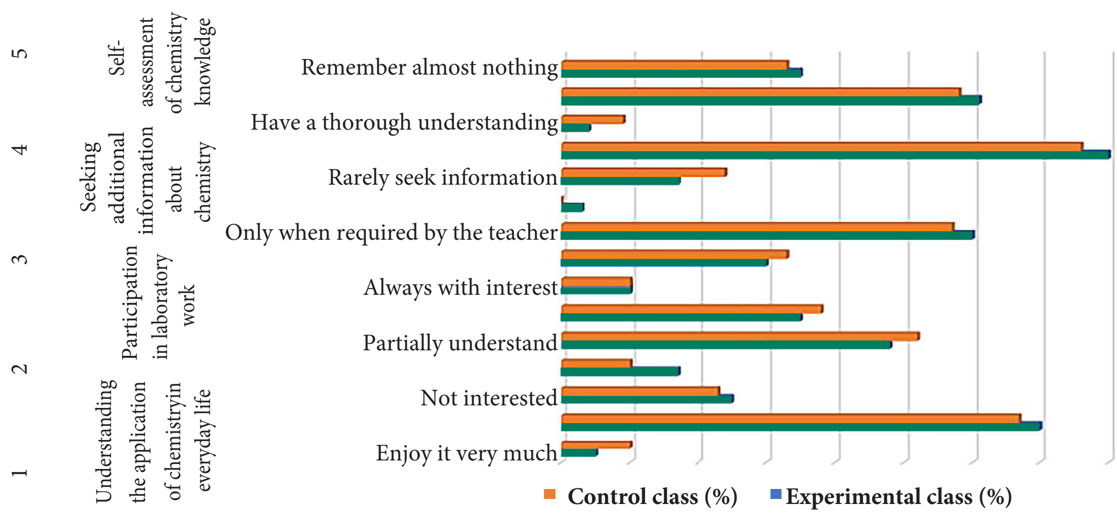

Figure 3. Comparative results of the questionnaire survey of pupils in the control and experimental classes at the initial stage
Source: compiled by the authors

The implementation of the maker education approach in chemistry teaching took place during the formative stage of the pedagogical experiment, during which pupils in the experimental class were involved in maker-based laboratory work, practical tasks, and mini-projects. The principal feature of the instructional process was the combination of research activities with elements of edutainment, involving the use of interactive tasks, team STEM challenges, and the creation of pupils' own experimental models. During the learning process, pupils in the experimental group completed various maker education tasks, including constructing a model of a galvanic cell from readily available materials, producing natural indicators for determining the acidity of solutions, designing simple devices for testing the electrical conductivity of substances, and conducting investigations of salt hydrolysis in the format of a "home pH laboratory". These activities required active group interaction, independent planning of experiments, analysis of the results obtained, and presentation of pupils' own developments. During one of the maker education activities, pupils in the experimental class designed simple devices for determining the electrical conductivity of substances using readily available materials, including batteries, LEDs, and connecting wires with crocodile clips (Fig. 4).

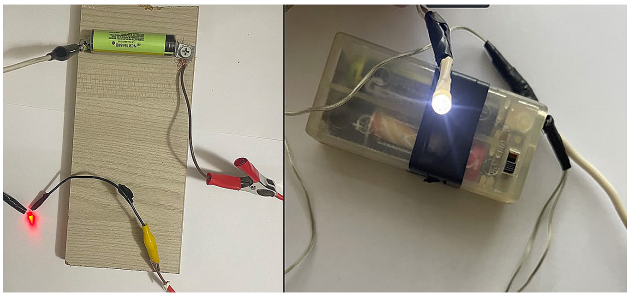

Figure 4. Devices for testing the electrical conductivity of substances, made by the pupils of the experimental class themselves
Source: compiled by the authors

The activity was organised in pairs or small groups, each of which constructed its own model of an electrical conductivity tester. Following a brief introduction and discussion of the operating principle of the device, pupils assembled the electrical circuit, tested its functionality, and investigated the conductivity of various substances. Samples of metals (Cu, Al), aqueous solutions of ionic compounds (NaCl, KCl), distilled water, and a sugar solution were used in the investigation. The results obtained were discussed within the groups and used to formulate conclusions regarding the electrical conductivity of different types of substances. In contrast to the experimental class, the investigation of electrical conductivity in the control class was carried out using a standard laboratory device demonstrated by the teacher, followed by a discussion of the observed results. Pupils recorded the findings in their exercise books; however, their participation was largely reproductive in nature and did not involve independent construction of devices or the organisation of experimental inquiry.

The results of classroom observations demonstrated that, during the completion of maker education tasks, pupils in the experimental class showed a noticeable increase in cognitive activity, initiative, and independence. They more frequently asked clarifying questions, proposed their own approaches to conducting experiments, and attempted to explain observed phenomena on the basis of their knowledge of chemical bonding and the structure of substances. One of the subsequent tasks at the formative stage of the pedagogical experiment involved constructing a model of a galvanic cell using readily available materials. Pupils in the experimental class worked in teams and were tasked with designing a chemical source of electric current using potatoes as a natural electrolyte.

At the initial stage of the activity, certain difficulties were encountered, as the voltage produced was insufficient to illuminate the LED because individual potatoes generated a potential difference of less than 1 V. Initially, the pupils connected the cells in parallel, which did not result in an increase in voltage. Through discussion and independent analysis of the situation, they concluded that a series connection of galvanic cells was required in order to increase the voltage (Fig. 5). This contributed to a deeper understanding of the operating principles of chemical power sources and promoted the development of collaborative problem-solving skills in experimental contexts.

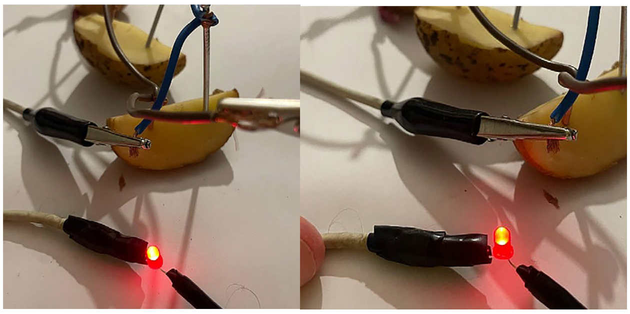

Figure 5. Series connection of potato galvanic cells for powering an LED
Source: compiled by the authors

During the activity, pupils investigated the possibility of reproducing the operation of a galvanic cell using household materials. The class was divided into groups, each employing different design variants. In the first case, potatoes were cut into sections, and a zinc nail and a copper wire were inserted into each piece. The individual cells were then connected in series to form an electrical circuit, to which an LED was attached. After the circuit was completed, the LED illuminated, confirming the generation of an electric current as a result of redox reactions. Another group of pupils implemented an alternative galvanic cell design (Fig. 6).

Figure 6. Model of a potato galvanic cell with a series connection of electrochemical cells
Source: compiled by the authors

For this purpose, three potatoes were used, each containing a zinc plate and a copper wire positioned in such a way that the electrodes did not come into contact with one another. The cells were connected in series using connecting wires with crocodile clips, forming an electrical circuit consisting of three electrochemical cells. An LED was attached to the outer electrodes and illuminated when the voltage reached approximately 1.8 V. The results obtained confirmed that potatoes can function as natural electrolytes, enabling the conversion of chemical energy into electrical energy. Furthermore, it was established that increasing the acidity of the medium, for example by adding vinegar, contributed to an increase in voltage, indicating the influence of electrolyte composition on the efficiency of the galvanic cell. From a pedagogical perspective, this activity possessed considerable potential for the development of pupils' research, experimental, and project skills. Working with simple materials stimulated cognitive interest, promoted the formation of cause-and-effect relationships between chemical and physical processes, and enhanced pupils' understanding of interdisciplinary links between chemistry, physics, and technology.

Overall, the results of classroom observations demonstrated that the use of maker education tasks, particularly the project "Create own galvanic cell", contributed to increasing pupils' interest, independence, and understanding of the nature of electrochemical processes. In the course of completing the activity, pupils not only confirmed the possibility of using potatoes as a source of electrical energy but also recognised that the efficiency of such a source depends on the number of electrochemical cells and the way in which they are connected. In order to determine the effectiveness of implementing the maker education approach in chemistry teaching, a comparative analysis of the results obtained by pupils in the control and experimental classes at the initial and formative stages of the pedagogical experiment was conducted. To generalise the findings, pupils' levels of cognitive activity were analysed on the basis of questionnaire responses and classroom observations. At the final stage of the pedagogical experiment, a repeated assessment of the levels of cognitive activity among pupils in both the control and experimental classes was carried out. The assessment took place after the completion of the formative stage and the study of the relevant chemistry topic. To ensure the comparability of the results, the same instruments used at the initial stage were employed, namely the questionnaire, classroom observations, and analysis of pupils' performance in learning tasks. Comparative analysis of the results obtained at the initial and final stages of the experiment demonstrated positive changes in the development of cognitive activity in both groups; however, the most substantial improvements were observed in the experimental class. In particular, the proportion of pupils with a high level of cognitive activity in the experimental class increased from 10% to 43%, whereas in the control class this indicator rose only from 10% to 17%. At the same time, the proportion of pupils with a low level of cognitive activity in the experimental group decreased from 43% to 9%, compared with a reduction from 47% to 31% in the control group. Statistical analysis using Pearson's χ^2 test confirmed that the differences between the groups at the final stage were statistically significant ($p < 0.05$). The findings were generalised and used to determine the dynamics of pupils' levels of cognitive activity. A comparative description of changes in pupils' levels of cognitive activity is presented in Table 1.

Table 1. Dynamics of the levels of cognitive activity among pupils in the control and experimental classes

Level of cognitive activity	Control class (before the experiment)	Control class (after the experiment)	Experimental class (before the experiment)	Experimental class (after the experiment)
High	10 %	17 %	10 %	43 %
Medium	43 %	52 %	47 %	48 %
Low	47 %	31 %	43 %	9 %

Source: compiled by the authors

The results of the study confirm the effectiveness of using maker-based tasks in the chemistry learning process. Involving pupils in constructing their own models, carrying out practice-oriented investigations and engaging in teamwork helped to stimulate cognitive activity, develop research skills and foster sustained motivation to study the subject. The practical findings of the study support the recommendation to incorporate maker tasks into the school chemistry curriculum, particularly in the form of mini-projects, STEM challenges and practical work on constructing simple devices. It is advisable to introduce such tasks both when studying topics such as electrochemistry, solutions, acids and bases, and in extracurricular activities, with the aim of enhancing pupils' cognitive engagement and learning motivation. The results obtained are consistent with the findings of other researchers who emphasise the effectiveness of using practice-oriented and activity-based approaches in teaching. In particular, the works of M. Honey & D.E. Kanter (2013) and E.R. Halverson & K.M. Sheridan (2014) note that involving pupils in design, experimental and project-based activities helps to increase learning motivation, develop cognitive activity and foster a lasting interest in learning.

The results obtained in this study not only confirm these findings but also expand upon them in the context of applying the maker approach as a means of implementing edutainment in chemistry teaching. In particular, it has been established that combining practical activities with elements of interactivity, creative design and teamwork creates favourable conditions for stimulating pupils' cognitive activity and fostering their intrinsic motivation to learn. In the academic literature, maker education is regarded as a pedagogical approach based on the ideas of constructivism and constructionism, which involves the acquisition of knowledge through active engagement, the creation of physical or digital objects, and the solving of practical problems. This approach is linked to the concept of learning by doing, according to which learning is most effective when learners are directly involved in practical activities and experimentation.

Considerable attention in contemporary research is devoted to analysing the development of maker education as a component of the STEM approach. In particular, A. Ioannou & B.E. Gravel (2024) investigated trends in the development of maker education and outlined the prospects for its transformation in the context of STEM+ and transdisciplinary learning. The authors emphasised the importance of the learning through making approach as the basis for integrating various educational disciplines. The study by C.E. George-Reyes *et al.* (2025) examined the development of maker education within an inclusive educational environment, particularly through the activities of makerspaces, and found that it contributes to the development of STEM skills and increases the engagement of various groups of learners. M. Schad & W.M. Jones (2020) conducted a systematic review of academic literature on the maker movement in education and concluded that the use of the maker approach fostered the development of critical thinking, practical skills and activity-based learning. Similar results were obtained in the study by M. Schad *et al.* (2025), which, based on a qualitative analysis, examined a chemistry teacher's experience of implementing maker-oriented teaching. The authors demonstrated that such activities help to increase pupils' engagement and develop practical skills in STEM education. The findings were consistent with the conclusions of this study, confirming the value of the maker approach as a means of integrating different educational disciplines and developing learners' practical skills.

Contemporary research emphasises that maker education creates new opportunities for organising activity-based and inquiry-based learning, as it promotes the active involvement of learners in the creation of their own projects, prototypes, and models. A systematic review of research on maker education notes that such approaches foster the development of creativity, critical thinking and collaboration skills, whilst also increasing pupils' interest in STEM subjects. These findings were consistent with the approach adopted in this study, in which maker activities are regarded as the foundation for developing the research and creative competences of future chemistry teachers. The researchers also emphasise that makerspaces create conditions for the integration of science, technology, engineering and mathematics through practical activities and design. Through the use of a variety of materials, digital technologies and engineering tools, pupils have the opportunity to experiment, develop their own projects and apply scientific knowledge in real-life situations (Nadal *et al.*, 2025). This confirms the value of using makerspaces in chemistry education, particularly for organising practice-oriented activities, which was a key component of the edutainment approach. At the same time, this study emphasises the combination of maker activities with edutainment, which broadens the scope for their application in the training of future chemistry teachers.

Furthermore, academic research emphasises that the introduction of maker approaches into the learning process has contributed to the development of an active stance among learners, as they acted not only as consumers of knowledge but also as creators of their own educational products. In the process of creating physical or digital artefacts, students can experiment with various technologies, analyse the results of their work and refine the models they have created, which has fostered a deeper understanding of the subject matter (Larson, 2024). At the same time, the studies analysed have not paid sufficient attention to combining maker activities with elements of edutainment, which highlights the need for further research in this area. Unlike the majority of previous studies, which primarily consider maker education as a tool for STEM learning, the present research focuses on its application as a means of implementing edutainment. Thus, the analysis of scientific sources indicates that maker education possesses considerable potential for organising activity-based, interactive, and creative learning. Nevertheless, the use of maker education as a means of implementing edutainment in the preparation of future chemistry teachers remains insufficiently explored, which determines the focus of the present study.

CONCLUSIONS

The study confirmed the appropriateness of using the maker education approach as a means of implementing edutainment in the methodological preparation of future chemistry teachers. An analysis of scientific and pedagogical sources demonstrated that the combination of practical activities, experimentation, and creative design provides favourable conditions for the development of research skills, critical thinking, and increased motivation to study the natural sciences. The results of the pedagogical experiment showed that, at the initial stage, medium and low levels of pupils' cognitive activity predominated in both groups under investigation, indicating insufficient interest in studying chemistry and a limited understanding of the practical significance of the learning material.

The introduction of maker education tasks incorporating elements of edutainment during the formative stage contributed to the activation of learning activities among pupils in the experimental class. In the course of completing practice-oriented tasks, including the construction of galvanic cell models, the design of devices for determining the electrical conductivity of substances, and the conduct of experimental investigations, pupils demonstrated higher levels of initiative, independence, and engagement with learning activities. Comparative analysis of the results obtained at the initial and final stages of the experiment revealed a substantial positive development in the cognitive activity of pupils in the experimental class. In particular, the proportion of pupils with a high level of cognitive activity increased from 10% to 43%, whereas in the control class this indicator rose only to 17%. At the same time, the proportion of pupils with a low level of cognitive activity in the experimental group decreased from 43% to 9%. These findings confirm the effectiveness of maker education tasks as a means of increasing motivation and stimulating pupils' cognitive activity in the process of learning chemistry.

Thus, the use of the maker education approach in combination with elements of edutainment contributed to the development of pupils' research, project, and communication skills, fostered their creativity, and enhanced their understanding of chemical phenomena through practical activities. The study identified the didactic potential of the maker education approach in the formation of subject-specific and key competences in chemistry, particularly the ability to conduct experiments, develop critical thinking, independently search for solutions, and apply acquired knowledge in practical life situations. In addition, a methodological model for organising maker education activities in chemistry teaching was developed, comprising successive stages of motivation, design, product creation, presentation of results, and reflection. The study also resulted in the creation of a series of maker education tasks and educational mini-projects for lessons and extracurricular activities, combining practical and creative components of learning and promoting the integration of chemistry with physics, biology, technology, and environmental studies.

The results obtained confirm the appropriateness of using the maker education approach as an effective means of implementing edutainment in the methodological preparation of future chemistry teachers. Involving student teachers in the development and implementation of maker education tasks within the educational process contributes to the formation of their professional competences, particularly the ability to design practice-oriented learning environments, organise pupils' research activities, and integrate innovative educational approaches into chemistry teaching. Prospects for further research include the development of a system of maker education practices for different topics within the school chemistry curriculum, as well as the exploration of opportunities for integrating the maker education approach with digital technologies, STEM education, and STEAM education in the professional preparation of future teachers of the natural sciences.

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Юлія Шафорост
Кандидат хімічних наук, доцент
Черкаський національний університет імені Богдана Хмельницького
18031, бульв. Шевченка, 81, м. Черкаси, Україна
https://orcid.org/0000-0002-0002-2803
Валентина Шпак
Доктор педагогічних наук, професор
Черкаський національний університет імені Богдана Хмельницького
18031, бульв. Шевченка, 81, м. Черкаси, Україна
https://orcid.org/0000-0003-0913-6150
Андрій Шафорост
Студент
Черкаський національний університет імені Богдана Хмельницького
18031, бульв. Шевченка, 81, м. Черкаси, Україна
https://orcid.org/0009-0003-3027-554X

Мейкерство як засіб реалізації едьютейнменту у навчанні хімії учнів старшої школи

Анотація. У сучасних умовах розвитку освіти важливого значення набуває використання інноваційних педагогічних підходів, спрямованих на підвищення мотивації здобувачів освіти та розвиток їхньої дослідницької і творчої активності. Одним із перспективних напрямів є поєднання едьютейнменту та мейкерської освіти. Метою дослідження було обґрунтування та експериментальна перевірка ефективності використання мейкерського підходу як засобу реалізації едьютейнменту в процесі навчання хімії учнів 11-х класів. У дослідженні було використано комплекс теоретичних та емпіричних методів: аналіз і узагальнення науково-педагогічної літератури, педагогічне моделювання, педагогічне спостереження, анкетування, бесіди та педагогічний експеримент. Результати педагогічного експерименту засвідчили, що на констатувальному етапі в обох групах переважали середній і низький рівні пізнавальної активності. У процесі формувального етапу учні експериментального класу виконували мейкерські завдання та мініпроєкти, що передбачали створення експериментальних моделей і проведення досліджень. Виконання таких завдань сприяло підвищенню пізнавальної активності, розвитку творчості та самостійності. Порівняльний аналіз результатів констатувального та підсумкового етапів показав підвищення рівня пізнавальної активності учнів експериментального класу: частка учнів із високим рівнем зросла з 10 % до 43 %, тоді як кількість учнів із низьким рівнем зменшилася з 43 % до 9 %. Отримані результати підтвердили ефективність використання мейкерських завдань як засобу активізації навчальної діяльності та підвищення мотивації до вивчення хімії. Практична цінність дослідження полягала у розробленні методичної моделі організації мейкерської діяльності та системи мейкерських завдань для навчання хімії, апробованих студентами під час педагогічної практики

Ключові слова: мотивація; пізнавальна активність; проєктування; експериментування; STEM-освіта