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Modern Chemistry Teaching

MULTIMEDIA AND DIGITAL RESOURCES

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Modern Chemistry Teaching
MULTIMEDIA AND DIGITAL RESOURCES

A guide for chemistry teachers enhancing the use of multimedia and digital tools in teaching, including virtual labs, simulations, and AI-based applications.

Electronic edition

Erasmus+ Project

Improvement the quality of chemistry teaching in VET in Bosnia and Herzegovina

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FOREWORD

This handbook was developed within the Erasmus+ project *"Enhancing the Quality of Chemistry Teaching in Vocational Education in Bosnia and Herzegovina – ChemTeach"* (101129417-ERASMUS-EDU-2023-CB-VET), with the aim of providing chemistry teachers with a framework for implementing modern, digitally supported, and multimedia-based approaches in education. The project brings together vocational secondary schools, universities, and employers, focusing on the development of teaching competences, the improvement of the quality of science education more broadly, and the preparation of students for active, inquiry-based, and contextual learning.

The project is coordinated by the Slovak University of Technology in Bratislava, while the team of the Faculty of Natural Sciences and Mathematics at the University of Banja Luka leads project activities in Bosnia and Herzegovina in cooperation with the Grammar School, the Medical School, and the Technology School in Banja Luka. Partners from Slovakia and the Czech Republic actively contribute to the exchange of good practices, the development of innovative teaching materials, and the integration of digital tools into the teaching process.

The handbook is intended for teachers of chemistry and related subjects, providing both theoretical and practical support for implementing competence-oriented and multimedia-enriched instruction. It focuses on the use of interactive simulations, virtual laboratories, digital visualizations, quizzes, portfolios, and tools based on artificial intelligence. These strategies enable active student engagement, the connection of chemistry to everyday life, and the development of critical thinking, creativity, and digital literacy. Examples of good practice, activity templates, and worksheets empower teachers as agents of change and facilitate the integration of digital resources into classroom practice.

Banja Luka and Bratislava, November 2025.

PREDGOVOR

Ovaj priručnik nastao je u okviru Erasmus+ projekta „Unapređenje kvaliteta nastave hemije u stručnom obrazovanju u Bosni i Hercegovini – ChemTeach" (101129417-ERASMUS-EDU-2023-CB-VET), sa ciljem da nastavnicima hemije pruži okvir za primjenu savremenih, digitalno podržanih i multimedijalnih pristupa u obrazovanju. Projekat okuplja srednje stručne škole, univerzitete i poslodavce, fokusirajući se na razvoj nastavničkih kompetencija, unapređenje kvaliteta nastave prirodnih nauka generalno i osposobljavanje učenika za aktivno, istraživačko i kontekstualno učenje.

Koordinator projekta je Slovački tehnički univerzitet u Bratislavi, dok tim Prirodno-matematičkog fakulteta Univerziteta u Banjoj Luci vodi projektne aktivnosti u Bosni i Hercegovini u saradnji sa Gimnazijom, Medicinskom i Tehnološkom školom u Banjoj Luci. Partneri iz Slovačke i Češke aktivno doprinose razmjeni dobrih praksi, razvoju inovativnih nastavnih materijala i integraciji digitalnih alata u nastavni proces.

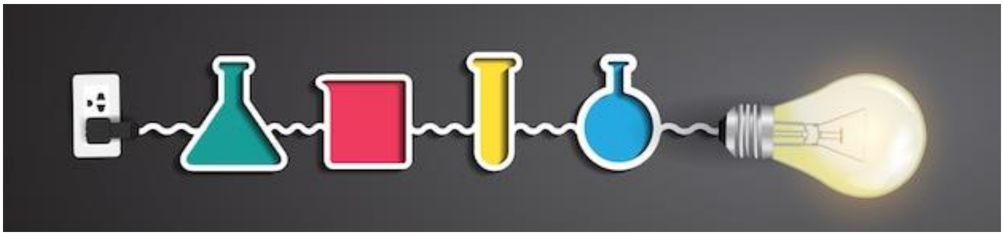
Priručnik je namijenjen nastavnicima hemije i srodnih predmeta, pružajući teorijsku i praktičnu podršku za realizaciju kompetencijski orijentisane i multimedijalno obogaćene nastave. Fokus je na korišćenju interaktivnih simulacija, virtuelnih laboratorija, digitalnih vizualizacija, kvizova, portfolija i alata zasnovanih na vještačkoj inteligenciji. Ove strategije omogućavaju aktivno uključivanje učenika, povezivanje hemije sa svakodnevnim životom i razvoj kritičkog mišljenja, kreativnosti i digitalne pismenosti. Primjeri dobre prakse, obrasci aktivnosti i radni listovi osnažuju nastavnike kao nosioce promjena i olakšavaju integraciju digitalnih resursa u nastavu.

Banja Luka i Bratislava, novembar 2025. godine

CONTENT

INTRODUCTION

Modern chemistry teaching requires more than traditional lecturing and theoretical explanation. Today's students learn through exploration, interaction, and the use of digital resources, which enables them to actively engage in the process of acquiring knowledge. Multimedia—combining text, images, animations, video materials, and interactive simulations—serves as a key tool for visualizing abstract chemical phenomena and strengthening the understanding of complex concepts.



This teacher's guide has been developed within the Erasmus+ project *"Improving the Quality of Chemistry Teaching in Vocational Education in Bosnia and Herzegovina"* (ChemTeach). Its purpose is to support high-quality chemistry education and to address the challenges of teaching in the natural sciences. The guide offers theoretical foundations and practical guidelines that help teachers plan and deliver instruction, develop students' competencies, and prepare them for applying chemistry in real-life contexts.

Special emphasis is placed on:

- the use of interactive simulations and virtual laboratories;
- the application of software for modelling molecules and chemical structures;

- the integration of quizzes, portfolios, and self-assessment in digital form;
- the use of artificial intelligence for data analysis and learning support.

The integration of multimedia and digital tools enables individualized learning, motivates students, and provides opportunities to actively explore chemical phenomena. At the same time, teachers are given practical resources and templates that facilitate lesson preparation and delivery, making instruction dynamic, interactive, and relevant to everyday life and contemporary society.

The aim of this guide is to create a functional framework for multimedia-based chemistry teaching, where technology and didactic approaches work together to help students develop not only knowledge, but also the competencies needed for critical thinking, problem solving, and creative action in both scientific and everyday contexts.

MODERN CHEMISTRY TEACHING: CONTEXT AND CHALLENGES

Chemistry in contemporary society forms the foundation for understanding the world around us. From the composition of materials and chemical reactions that drive life processes, to innovations in energy, medicine, and environmental protection—chemistry connects the natural sciences with everyday life and societal development.

In an era marked by rapid technological change, climate challenges, and an increasing need for sustainable development, there is a clear demand to introduce chemistry education as early as possible, but in a new and adapted way. Chemistry teaching no longer simply involves memorizing facts and formulas; it focuses on developing students' essential skills for critical thinking, problem solving, teamwork, and the responsible use of scientific knowledge. These competencies form the basis for understanding the complex phenomena of the modern world and for making informed decisions.

Modern educational approaches place the student at the center of the learning process. The teacher is no longer the sole source of knowledge, but rather a mentor, researcher, and designer of experiences that connect theory with the students' real-life environment. Therefore, the primary challenge of contemporary chemistry teaching for every teacher is how to enable the acquisition of chemical knowledge and skills while simultaneously effectively developing scientific literacy and 21st-century competencies through mastery of fundamental chemical concepts.

Digital technologies, multimedia, and innovative teaching methods open new opportunities for interactive and experiential chemistry learning, tailored to the needs and interests of today's students. This requires a thoughtful combination of traditional and digital approaches, integration of practical work, collaboration, reflection, and continuous professional development of teachers in the digital age.

THE ROLE OF CHEMISTRY AS A SCHOOL SUBJECT IN MODERN EDUCATION

Chemistry is a science that connects the microstructure of matter with the macro phenomena we observe in everyday life: from the composition of food and medicines to processes in the natural environment and industry. In education, the subject of chemistry should not be merely a collection of facts and formulas; it is essential to continuously emphasize and develop its core purpose and function as a means to foster students' abilities to understand cause-and-effect relationships, interpret data, and make informed decisions.

This approach for teachers has practical implications for the teaching process. In short, it means that the teacher moves away from the traditional method of merely demonstrating steps and formulas in class, and instead presents students with situations in which they themselves identify the connections between chemical principles and real-world problems. Simple examples include investigating the effect of temperature on food preservation, studying the behavior of detergents in water, or exploring the composition of cosmetic products and the safety of their use, topics which will be discussed further later in this chapter.

COMPETENCIES AND CHEMISTRY EDUCATION

In the first *Modern Chemistry Teaching* guide, we have explored competencies and learning outcomes in the context of chemistry education in detail, including definitions, classifications, and practical examples of classroom application. In this guide, we provide only a concise introduction to 21st-century competencies, in order to connect them with the topic of multimedia in chemistry teaching and illustrate their role in contemporary pedagogical approaches.

21st-century competencies represent a combination of knowledge, skills, attitudes, and abilities that enable students to act effectively, responsibly, and independently in various learning, work, and everyday contexts. They encompass not only what a student knows but also the ability to apply that knowledge and skills in real-life situations.

In contemporary education, competencies are developed through clearly defined learning outcomes, which represent measurable steps toward achieving a broader goal - a competency. An example in chemistry teaching:

- **Competency:** Developed scientific literacy and the ability to apply chemical concepts in everyday life.
- **Learning outcome:** The student explains the properties and uses of soaps and detergents based on the chemical structure of their molecules.

According to the European Union framework for key competences for lifelong learning (2006, revised 2018), eight key competences have been identified: linguistic literacy, foreign language communication, mathematical and scientific competence, digital competence, learning to learn, personal and social development, civic competence, entrepreneurial competence, and cultural awareness.

In addition to key competences, generic (or transferable) competences are important, as they are developed across all subjects, projects, and extracurricular activities:

- Communication and collaboration
- Critical thinking and problem solving
- Time management and independent learning
- Digital literacy
- Ethical and responsible behavior

In the context of multimedia in chemistry teaching, these competencies enable students to effectively use digital tools for research, simulations, presentations, and data analysis, while also developing critical thinking, creativity, and teamwork skills in a digital environment.

Table 1 provides an overview of key and generic competencies that serve as a basis for planning teaching activities in the context of multimedia-based chemistry education. Concrete examples of their application in chemistry will be presented in later chapters, through lesson designs, laboratory activities, and digital projects.

Table 1. Key and Generic Competencies

Type of Competence	Description / Focus
Key Competencies	*Knowledge, skills, and attitudes needed for life, work, and lifelong learning*
Linguistic and Communication Literacy	Ability to understand and convey information
Communication in Foreign Languages	Understanding and expressing oneself in a foreign language
Mathematical, Scientific, and Technological Competence	Application of mathematics and scientific principles
Digital Competence	Use of digital tools and media
Learning to Learn	Independent planning and monitoring of learning
Civic Competence	The ability to act as responsible citizens by understanding social, economic, and political structures.
Entrepreneurship	The ability to leverage ideas and transform them into value, and to be resourceful and initiative-driven.
Cultural Awareness	Understanding cultural context and expression
Generic Competencies	*Transferable skills for various contexts*
Critical Thinking	Data analysis and drawing conclusions
Problem Solving	Designing and implementing solutions
Teamwork and Collaboration	Effective coordination within a group
Time Management	Planning and organizing activities
Independent Learning	Taking responsibility for one's own learning
Digital Literacy	Effective use of technology
Ethical and Responsible Behavior	Application of moral principles and safety standards

CHANGES IN LEARNING APPROACHES AND THE ROLE OF THE TEACHER

The most important changes in learning and teaching approaches include:

- **Inquiry- and experiment-based activities** – students learn through practical experience, independent observation, and conducting experiments;
- **Problem- and project-based learning** – linking curriculum content with real-life and local contexts increases motivation and understanding;
- **Use of digital tools** – simulations, modeling, visualizations, and virtual laboratories enable deeper understanding of chemical phenomena and allow experiential learning even when hands-on work is not possible.

In practical terms, this approach requires students to:

1. Formulate questions and propose hypotheses;
2. Design simple experiments or research tasks;
3. Collect and analyze data;
4. Draw conclusions and relate them to real-life situations or scientific principles.

EXAMPLES OF ACTIVITIES AND LESSON DESIGNS

This section presents examples of teaching activities that teachers can adapt to the students' age and the key chemical concepts being taught. The aim of these examples is to provide inspiration and practical guidance for active, inquiry-based, and experiential chemistry learning.

For primary school students, it is recommended to focus on macroscopic phenomena from everyday life that students can directly observe and analyze. Activities should be designed so that students gradually recognize cause-and-effect relationships and develop basic skills in observation, questioning, and drawing simple conclusions. Examples may include changes of state, food reactions under different conditions, or observing the physical properties of substances.

For high school students, more complex chemical concepts can be introduced, linking macroscopic observations with the microscopic and symbolic levels of chemical knowledge. Teachers can use experimental tasks, simulations, multimedia presentations, and digital tools to enable students to investigate reactions, model molecular structures, or follow the kinetics of chemical processes.

It is important to note that lesson planning remains within the teacher's discretion and creativity, allowing them to choose the method of conducting activities, the level of complexity, and the degree of guidance according to their own judgment and the needs of the students. The examples provided below are not intended as strict instructions, but as inspiration and a starting point for creating learning experiences that develop scientific literacy, critical thinking, and 21st-century competencies.

Effect of Temperature and Humidity on Food Storage

At the beginning of the lesson, the teacher poses the question: *"Why does a rusk become soft after coming into contact with moist food?"* Students reflect and share their experiences, while the teacher moderates the discussion and records key terms: water, moisture absorption, chemical changes in starch.

Next, students are divided into small groups and tasked with observing various types of household foods and suggesting how temperature or storage conditions might affect their quality. Following this, they conduct a simple experiment – placing a small piece of rusk in a moist environment at room temperature and at a low temperature – and record the changes over time.

At the end of the lesson, the groups present their observations and discuss the chemical processes involved (water absorption, starch texture changes) as well as practical implications for food storage.

Studying the Properties of Detergents and Surface Tension

The teacher begins the lesson by asking: *"Why does soap make it easier to remove grease from a plate?"* Students share their hypotheses, while the teacher introduces concepts such as surface tension, detergent structures, and molecular polarity.

A group of students is tasked with observing the effect of soap on the mixing of water and oil and recording their observations. Afterwards, they discuss the role of the polar and nonpolar parts of molecules in cleaning.

At the end of the lesson, students relate their observations to everyday situations, such as washing dishes or hands, and draw conclusions about the chemical principles of surface tension and intermolecular interactions.

Composition of Cosmetic Products and Safety of Use

The teacher begins the lesson by asking: *"What does it mean when a cream is labeled hypoallergenic?"* Students investigate the composition of various cosmetic products based on their labels. Working in groups, they identify and categorize ingredients into active substances, preservatives, and additives. The teacher then guides a discussion on concentrations, pH values, and possible interactions between ingredients.

Chemical Reactions

The teacher begins the lesson by asking: *"Why does mixing baking soda and vinegar produce a gas?"* Students propose hypotheses and potential reactions, then carry out an experiment by mixing small amounts of baking soda and vinegar and measuring the volume of gas released.

Students record the relative reaction rates and other observations, and discuss the effects of temperature or concentration on the rate of CO_2 release. At the end of the lesson, they analyze the results, connect the chemical processes to everyday experiences (e.g., baking), and submit a short report.

ACTIVE LEARNING AND THE STUDENT-CENTRED APPROACH

In modern chemistry education, the student is at the center of the learning process. Active learning enables knowledge to be constructed through exploration, experimentation, and problem-solving. The teacher acts as a mentor and facilitator, designing activities that connect theory with students' real-life experiences and encourage their curiosity, independent reasoning, and responsibility for their own learning.

Digital and multimedia tools further enable interactive learning, data visualization and analysis, as well as the presentation of results. The following sections provide practical guidelines, methods, and examples for applying active learning in chemistry teaching

PRINCIPLES OF ACTIVE LEARNING

Active learning is based on several key principles:

- **Learning through experience**, where students collect data themselves, conduct experiments, and interpret results.
- **Authenticity of tasks,** in which real-life problem situations increase student motivation and the applicability of knowledge.
- **Metacognition and reflection** – an independent learner thinks about and analyzes learning strategies and processes.
- **Differentiation**, where the teacher adapts activities to different levels of prior knowledge and learning styles.

STRATEGIES AND METHODS

Experiments

Objective: Students directly test theoretical claims.

Approach: Ranges from whole-class demonstrations to team-based laboratory tasks. Students formulate hypotheses, take measurements, and record observations.

Safety: Laboratory conduct rules, basic protective equipment, and clear instructions are mandatory.

Inquiry-based learning

Objective: Develop students' research skills, critical thinking, and independence.

Approach: Students formulate questions, plan experiments, collect data, analyze results, and draw conclusions. Provide clear guidance for more complex tasks and allow room for creativity in the investigative process.

Application: Suitable for projects or multi-day activities. Digital tools can be integrated for data collection and visualization.

Debates and argumentation

Objective: Build the ability to present arguments, critically evaluate evidence, and engage in structured teamwork discussions.

Approach: Organize structured debates in which students prepare arguments and counterarguments. Encourage analysis of scientific and social aspects of the issue. Clearly define evaluation criteria at the beginning and include peer assessment.

Examples: GMOs, renewable energy sources, use of plastics, climate change.

Projects

Objective: Integrate knowledge from multiple subjects and apply chemistry to real-world problems.

Approach: Interdisciplinary work connects chemistry with biology, ecology, technology, and social sciences. Students work in teams, collect and analyze data, and present their results. Assign tasks according to students' abilities and interests. Use digital tools for data collection, graph creation, and result presentation.

Example: Analysis of water quality from local sources, preparation of a recommendation for the local community, and a public presentation.

EXAMPLES OF ACTIVITIES

One-day Workshop: Chemistry in My Kitchen

Objective: Explore and understand the changes that occur during cooking and baking, such as protein denaturation and the Maillard reaction. Develop experimental skills.

Activity Flow: Formulating hypotheses → Conducting experiments → Data analysis → Writing a report

School Project: Water in My Environment

Objective: Develop data analysis skills and understand the impact of pollution on the local community. Enhance experimental skills.

Activity Flow: Sampling → Conducting experiments (measuring pH and other parameters) → Data interpretation → Preparing recommendations and public presentation

EVALUATION OF ACTIVITIES AND STUDENT REFLECTION

Assessment in modern chemistry teaching follows the learning process, not just the final outcome. Students are evaluated not only on correct answers but also on their reasoning, collaboration, creativity, and ability to recognize and improve their own progress.

The contemporary approach combines **formative** and **summative assessment**:

- **Formative assessment** monitors students during the learning process through notes, discussions, short quizzes, reflections, and feedback that guides further work. The goal is for students to understand how they learn and what they can improve.
- **Summative assessment** takes place at the end of a topic, project, or experiment, when students present results, prepare a report, or submit a final portfolio. The focus is on an integrated evaluation of knowledge, skills, and attitudes developed during learning.

This approach gives teachers a complete picture of student progress, while students receive clear feedback and develop self-assessment skills.

Developing self-aware learning is based on reflection, a process in which students think more deeply about their learning—what they learned, how they learned, and how they can progress further. Synonyms for reflection found in the literature include self-reflection, thinking about learning, and metacognitive thinking.

Reflection helps students to:

- Recognize their own learning strategies and understand their advantages and limitations;
- Identify the connection between theory and practice;
- Develop responsibility and independence in learning.

Methods and tools that support these principles include:

STUDENT PORTFOLIO

- Contains activity plans, notes, experiment results, photos, videos, and short reflections.

- Enables formative and summative monitoring of progress

ASSESSMENT RUBRICS

- Criteria: safety and organization of work, clarity of hypothesis, accuracy of method, data interpretation, teamwork, and quality of presentation.
- Scoring scale, e.g., from 1 to 5.

SELF-ASSESSMENT AND PEER ASSESSMENT

- Students evaluate their own contribution and team work according to predefined criteria.
- Encourages the development of metacognition, responsibility, and objective self-evaluation.

STUDENT REFLECTION

- After each activity, students complete a short reflective note: *What did I learn? What was difficult for me? What would I do differently next time?*

Additional tools for adaptation

In modern chemistry teaching, it is important to adapt activities to students' abilities, use digital tools, and always ensure safety.

DIFFERENTIATION

- Advanced students should be offered extended tasks, e.g., quantitative analysis or statistical data processing.
- Students who need support should be provided with instructions, templates, and examples.

DIGITAL TOOLS

- Use molecular modeling simulations, online databases, digital forms for data collection, and collaborative presentation platforms.

LABORATORY SAFETY

- Laboratory rules are clearly defined.
- The use of chemicals and equipment is carefully planned.
- Personal protective equipment is mandatory for all activities.

MULTIMEDIA IN CHEMISTRY TEACHING

MULTIMEDIA – CONCEPT AND MEANING

The term ***multimedia*** originates from the Latin words multi (many) and medium (means, intermediary) and, in the broadest sense, refers to the use of multiple media—text, images, sound, animation, and video—to convey information, ideas, or emotions. In modern society, multimedia has become a dominant form of communication, as it combines visual, verbal, and auditory elements into a unified experience.

Today, multimedia appears in almost all spheres of life: from art, advertising, and media, to science, industry, and education. Its key feature is **interactivity**—the user's ability to actively control the flow of information, select content, and participate in the communication process. In this way, multimedia goes beyond simple presentation and becomes a dynamic system of interaction between humans and digital content.

The main components of multimedia include:

- **Text** – as a carrier of conceptual meaning,
- **Images and graphics** – which facilitate visual recognition and memory,
- **Sound and speech** – which enhance emotional experience and understanding,
- **Video and animation** – which depict motion and change,
- **Interactive elements** – which give the user the role of an active participant.

From a technical perspective, multimedia relies on the development of information and communication technologies (ICT), which enable the digital integration of various formats into a single whole. From a communication perspective, it changes the way information is perceived: the message is no longer linear or one-dimensional, but multi-channel and non-linear, engaging multiple senses simultaneously.

In this sense, multimedia can be viewed as a cultural phenomenon of the modern era, shaping our perception of the world and the way we learn. While traditional media, such as printed text or images in a book, required linear attention and interpretation, multimedia content encourages non-linear and interactive thinking, adapted to the rhythm of the digital society.

Conclusion

Multimedia is not merely a collection of technical tools; it represents a relatively new form of expression and thinking, combining knowledge, images, sound, and interaction into a unified experience.

MULTIMEDIA IN THE EDUCATIONAL CONTEXT

When multimedia is viewed in an educational context, the shift from entertainment and communication to learning and teaching becomes clear. When introduced in schools, multimedia becomes a didactic tool that allows the integration of various forms of knowledge presentation and the adaptation of learning to the diverse needs of students.

The purpose of multimedia in education is not technical attractiveness, but **pedagogical functionality**—how different media can work together to support understanding, memory, and the application of knowledge.

According to the **cognitive theory of multimedia learning** (Mayer, 2001), students learn best when information is presented through a combination of words and images, as this activates two channels of information processing—the verbal and the visual. The theoretical foundation of this idea comes from the **dual coding theory** (Paivio, 1986), which states that information presented simultaneously in verbal and visual form is remembered better than information presented through a single channel.

Mayer defined several principles that explain how multimedia can enhance the learning process:

- Students learn better when images and text form a coherent whole (**principle of contiguity**).
- When extraneous elements are excluded (**principle of coherence**).
- When information is divided into smaller segments (**principle of segmenting**).
- When narration is used instead of reading text (**principle of modality**).

In practice, this means that students should not be passive observers, but active participants who connect visual and verbal information into meaningful knowledge. Well-designed multimedia allows students to explore, analyze, predict, and explain phenomena – in other words, to learn *actively* and *reflectively*.

Multimedia also fosters the development of digital, visual, and media literacy, recognized as key competencies of the 21st century. Through multimedia materials, students not only learn chemistry but also engage in shaping information: creating presentations, animations, videos, or digital posters, thereby acquiring communication and self-expression skills. Multimedia does not replace traditional teaching methods – it complements them, creating a richer, more interactive, and meaningful learning environment

Conclusion

In an educational context, multimedia is not merely a means of presentation but a bridge between theory and experience. It allows students to "see" phenomena that would otherwise be invisible, connect them with their own understanding, and, through active interaction, construct lasting and functional knowledge.

ARTIFICIAL INTELLIGENCE IN CHEMISTRY TEACHING – A NEW LEVEL OF DIGITAL INTERACTION

Key concept

Artificial intelligence does not replace the human role in teaching; rather, it expands its possibilities—it helps teachers better understand their students and enables students to actively construct knowledge through interaction with an intelligent system.

THEORETICAL FRAMEWORK AND THE SIGNIFICANCE OF ARTIFICIAL INTELLIGENCE IN EDUCATION

Artificial Intelligence (AI) refers to the capability of machines and computer systems to emulate certain aspects of human intelligence—to learn from data, recognize patterns, make decisions, and communicate with users in a natural way. In the educational context, AI is not merely about technical automation, but about providing intelligent support for learning: personalizing content, analyzing progress, enabling adaptive assessment, and facilitating interactive communication.

Contemporary definitions (Holmes et al., 2021; UNESCO, 2023) emphasize that the goal of AI in education is to enhance the quality, inclusivity, and efficiency of learning, rather than to replace teachers. AI is viewed as a learning partner, providing better access to information, timely feedback, and individualized support for each student.

From a didactic perspective, AI expands the framework of traditional and multimedia teaching. While multimedia combines multiple modes of presentation (text, images, sound), AI adds a dimension of intelligent interaction and adaptation. This means that teachers no longer deliver pre-prepared content in the same way to all students, but can use tools that automatically suggest additional explanations, exercises, and simulations tailored to individual needs.

APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN CHEMISTRY TEACHING

Chemistry is a science in which many processes are microscopic and abstract, so understanding them requires visualization and the integration of different levels of knowledge—macroscopic, microscopic, and symbolic. In this context, AI can enhance multimedia approaches by enabling:

- **Generation of visual representations:** tools such as generative models (e.g., ChatGPT, Copilot, Gemini) can create images of molecules, reactions, or 3D structures for students to explore.
- **Virtual laboratories with intelligent guidance:** an increasing number of AI-based platforms offer experiment simulations that adapt task complexity to students' knowledge levels.
- **Automatic recognition of chemical formulas and equations:** systems combining OCR and AI assist in digitizing notes and verifying the accuracy of chemical expressions.
- **Intelligent assistants:** tools like ChatGPT allow students to ask

questions, request explanations, check their understanding, and receive individualized real-time feedback.

- **Learning analytics:** AI can track student work patterns (e.g., types of tasks most frequently answered incorrectly) and provide teachers with data to adjust instruction.

In such an environment, the teacher becomes a **learning designer**, not just a lecturer—they select and combine tools, pose questions, design inquiry-based tasks, and guide students in reflecting on results generated by AI.

Practical example

The topic "Effect of Temperature on the Rate of a Chemical Reaction" can be explored using an AI-based virtual laboratory. Such a system allows students to modify parameters that influence the reaction rate (temperature, concentration, pressure) and observe real-time changes in graphs and/or molecular models. Students can use ChatGPT to analyze results, formulate conclusions, and write a report on the laboratory investigation. The entire process involves experimentation, analysis, and discussion of results—three fundamental phases in forming a scientific conclusion.

PEDAGOGICAL, ETHICAL, AND SOCIAL ASPECTS

The introduction of artificial intelligence in teaching requires careful consideration of pedagogical principles and ethical boundaries. The key question is not whether AI will replace the teacher, but how it will change the way teachers teach and students learn.

The pedagogical challenge lies in preserving students' critical and reflective thinking—ensuring they do not become passive consumers of "ready-made answers," but active investigators who use AI as a tool rather than an authority. Teachers must instruct students in digital ethics, source verification, and responsible use of technology, including recognizing the limitations and potential errors that AI may produce.

The ethics of AI application in education encompasses issues such as data privacy, algorithmic transparency, and equitable access to technology. In practice, this means that schools and teachers should select tools that are safe, open, and aligned with educational objectives rather than commercial interests.

At the same time, AI introduces a societal dimension to the changing role of knowledge—in a world where information is available in seconds, the goal of education shifts to developing critical thinking, creativity, and problem-solving skills, rather than merely reproducing facts.

Conclusion

Artificial intelligence in chemistry teaching is not merely a technological trend, but a pedagogical transformation. Combined with multimedia approaches, it creates an environment in which the student learns through dialogue, investigation, and reflection, while the teacher becomes a mentor guiding them through the complex world of knowledge and digital information. The combination of multimedia and artificial intelligence in modern chemistry education allows science to be brought closer to real life—through interactivity, visualization, and personalized learning.

DIGITAL TOOLS AND E-LEARNING IN CHEMISTRY

Key concept

Digital tools in chemistry teaching do not change the essence of learning – they deepen it, opening up new ways to understand, explore, and apply knowledge.

The development of digital technologies in recent decades has strongly influenced the way knowledge is created, shared, and applied. In education, digital transformation does not simply mean switching to electronic platforms; it also signifies a paradigm shift in learning—from passive information acquisition to active, autonomous, and collaborative learning.

In chemistry teaching, which naturally combines theory, experimentation, and visualization, digital tools hold a special place. They make abstract concepts and invisible processes visible, understandable, and accessible to students with varying levels of prior knowledge. Through e-learning platforms, simulations, interactive visualizations, and virtual laboratories, students can explore chemical phenomena, formulate hypotheses, track results, and analyze data in a safe and motivating environment.

Digital tools thus extend the boundaries of the classroom and make the learning process **continuous and adaptable** — learning can take place anytime and anywhere. At the same time, teachers gain new opportunities for individualized instruction, formative assessment, and the development of students' digital competencies.

In the context of modern chemistry education, e-learning and digital tools are not merely technical support; they have become an integral part of the teaching strategy, connecting technology, science, and pedagogy into a coherent and functional whole.

DIGITAL TOOLS AND E-LEARNING – CONCEPT AND IMPORTANCE

Key concept

Digital tools are not a replacement for traditional learning, but a means of making instruction more flexible, interactive, and aligned with the ways in which students today naturally communicate and acquire knowledge.

Digital learning (e-learning) is a form of education based on the use of digital technologies and the internet in the process of delivering knowledge, communication, and assessing student achievement. Unlike traditional learning, which takes place exclusively in the classroom, e-learning enables flexibility in terms of time, space, and modes of accessing content. In this sense, it is not limited only to "online teaching," but encompasses a broader range of digital practices that support active, independent, and collaborative learning.

In the context of modern chemistry teaching, digital tools have become an essential part of the instructional process because they allow the visualization of complex concepts and chemical processes, the execution of virtual experiments, and communication and exchange of ideas between students and teachers. In this way, chemistry—as an experimental science that requires understanding of microscopic processes and models—particularly benefits from the use of digital media.

Digital tools in education do not merely imply the use of computers, but also the integration of various software platforms, simulations, applications, and visual tools that enable students to explore, analyze, and apply chemical concepts in real-life contexts.

The key value of e-learning does not lie in technology itself, but in the pedagogical purpose of its use: how the teacher uses digital resources to facilitate learning, enable individualized instruction, increase motivation, and develop students' digital competencies.

DIGITAL LEARNING PLATFORMS

Platforms such as Moodle, Google Classroom, and Microsoft Teams enable course organization, material distribution, communication, and monitoring of student activities. They can be used both in traditional and hybrid teaching models.

- **Moodle** is an open and flexible platform that allows teachers to create digital courses, quizzes, forums, and databases. In chemistry teaching, it can be used to organize thematic modules (e.g., "Organic Compounds," "Chemical Reactions"), where the teacher uploads presentations, assignments, video recordings of experiments, and additional materials.
- **Google Classroom** offers a simple and intuitive way to organize

content, assignments, and communication. It is particularly suitable for blended learning, as it allows real-time document sharing and collaboration on joint projects.

- **Microsoft Teams** combines video conferencing, collaborative work, and material storage. Teachers can organize virtual laboratory sessions, consultations, and group discussions, which is especially useful when students do not have access to a physical laboratory.

Recommendation

When choosing a platform, it is important for the teacher to be guided by the didactic goal—whether the aim is to encourage discussion, check understanding, enable independent learning, or organize collaborative activities. Technology should serve the pedagogical purpose, not the other way around.

ONLINE EXPERIMENTS AND SIMULATIONS

The experimental component is at the core of learning chemistry. However, in many schools the performance of real experiments is limited by a lack of equipment, chemicals, or adequate space. In such situations, digital simulations and virtual experiments provide a valuable alternative.

The most well-known and commonly used digital resources include:

- **PhET Interactive Simulations** – a platform from the University of Colorado offering interactive simulations of chemical, physical, and biological phenomena. Students can visually explore reactions, kinetics, equilibrium, atomic and molecular structure, change parameters, and observe the outcomes.

- **ChemCollective** – an online laboratory in which students can perform virtual experiments, measure concentrations, prepare solutions, and analyze results, thereby developing research and analytical skills.
- **MolView** – a tool that provides three-dimensional visualization of molecules and crystal structures, helping students better understand spatial structure and the relationships between structure and substance properties.

Virtual experiments cannot fully replace the experience of working in a real laboratory, but they can significantly enhance the understanding of abstract concepts and increase student motivation. They allow students to explore without the fear of making mistakes, as the process is safe and repeatable.

Conclusion

Simulations give students the opportunity to independently manipulate variables and immediately see the consequences of their decisions, thereby fostering investigative and experimental thinking.

TOOLS FOR VISUALISING CHEMICAL STRUCTURES

Visualization is one of the most important aspects of learning chemistry. Teachers often need to bridge the gap between the macroscopic world (what can be seen) and the microscopic world (atoms and molecules). Digital tools facilitate this process by enabling three-dimensional representations of structures, molecular rotation, and observation of geometry, hybridization, and intermolecular forces.

Examples of useful tools include:

- **Avogadro** – free software for drawing and visualizing molecules, useful for demonstrating the structure of organic compounds and reactions.
- **Jmol** – an interactive tool that allows 3D molecular visualization, with the option to embed it in presentations or web pages.
- **ChemSketch** – a tool for drawing chemical structures and reactions, helpful in preparing teaching materials and assignments.

These tools help students develop spatial chemical literacy, i.e., the ability to mentally connect the structure, properties, and behavior of matter.

ADVANTAGES, LIMITATIONS, AND RECOMMENDATIONS FOR USE

The use of digital tools in chemistry teaching brings numerous advantages:

- Increases student motivation and engagement,
- Enables individualized learning and independent exploration,
- Encourages visual and interactive understanding of abstract concepts,
- Facilitates communication and monitoring of student progress.

However, there are also certain limitations:

- Technical disparities between schools (lack of devices, internet connectivity),
- Risk of information overload and distractions,
- The need for continuous digital training for teachers,
- Risk that technology becomes an end in itself, rather than a means of learning.

Recommendations

1. **Introduce technology gradually and purposefully, in alignment with the learning objectives.**
2. **Combine digital and traditional methods – a hybrid approach yields the best results.**
3. **Engage students in creating digital materials (e.g., making video explanations or digital posters).**
4. **Evaluate the effectiveness of digital resources and adapt them to different types of learners.**

Conclusion

Digital tools in chemistry teaching are not merely technical solutions; they are an integral part of modern pedagogical practice, enabling students to learn through interaction, inquiry, and creative expression. Their power lies in the combination of science, technology, and didactics—in the teacher's skill to transform digital resources into meaningful learning experiences.

CHAPTER VI

ASSESSMENT AND EVALUATION IN DIGITAL CHEMISTRY TEACHING

A general discussion on the evaluation and assessment of student achievements was already presented in section 2.4. In this chapter, we provide a brief overview with a focus on digital teaching. Students are the central element of the teaching process, and modern chemistry instruction combines active learning, multimedia, digital tools, and artificial intelligence.

Traditional approaches to assessment are no longer sufficient—evaluation should support learning, motivate students, and provide feedback that enhances their competencies. Digital tools and intelligent systems make it possible for assessment to be dynamic, interactive, and tailored to individual student needs.

Formative and summative assessments complement each other: formative assessment monitors progress and provides feedback that supports learning, while summative assessment evaluates achieved outcomes and gives insight into the overall effectiveness of the process. Active learning also involves self-assessment, which helps students reflect on their knowledge, and peer assessment, which develops collaboration, critical thinking, and the ability to constructively evaluate the work of others.

DIGITAL TOOLS FOR EVALUATION

Digital tools today play a key role in modern chemistry teaching, enabling efficient, interactive, and adaptable assessment of student achievements. They not only help teachers monitor student progress and provide timely feedback but also allow students to actively participate in the evaluation process. By using digital tools, assessment becomes a dynamic and motivating element of teaching, tailored to the individual needs of each student.

Examples of digital tools include:

- **Quizzes and interactive tests** (Kahoot, Quizizz, Socrative) – besides providing instant feedback and automatic scoring, these tools introduce elements of gamification and competition, further motivating students.
- **Digital portfolios** (Google Sites, Seesaw) – allow documentation and tracking of individual and group work, student reflection, and the demonstration of competencies over time, including experimental results and multimedia materials.
- **Surveys and self-assessments** – help students recognize their strengths and weaknesses, evaluate their understanding of

concepts, and set goals for further learning.

- **Learning analytics** – platforms such as Moodle and Teams enable teachers to closely monitor activities, engagement, and student performance, and to identify areas requiring additional support or extra challenges for advanced learners.

Conclusion

Digital tools make assessment transparent, interactive, and available in real time. They increase student engagement, support independent learning, and enable teachers to better tailor instruction to individual and group needs.

EXAMPLES OF ASSESSMENT INSTRUMENTS

In modern chemistry teaching, assessment is no longer based solely on traditional tests; it incorporates a variety of instruments that enable comprehensive evaluation of students' knowledge, skills, and competencies. Examples of such instruments include:

1. **Formative quiz after an experiment** – questions are designed to check understanding of chemical processes, analyze results, and apply learned concepts in practical contexts. This type of task provides immediate feedback and helps the teacher adjust subsequent activities according to students' needs.
2. **Chemistry research portfolio** – students document the entire research process: hypothesis formulation, conducting experiments, collecting results, and reflection. Digital portfolios allow inclusion of

images, videos, and graphical representations, strengthening the visual and critical presentation of their work.

3. **Peer evaluation of project presentations** – students exchange opinions and provide constructive feedback using clearly defined criteria such as accuracy, creativity, methodological rigor, and teamwork. This instrument develops critical thinking and social competencies.

4. **Independent digital tasks in a virtual laboratory** – enable students to simulate experiments, analyze results, and produce reports, while the teacher can monitor the process and individual progress.

5. **Interactive tasks on a multimedia platform** – combining text, images, animation, and interactive elements, these tasks test understanding of key chemistry concepts, connect theory with practice, and increase student engagement.

Conclusion

The use of diverse assessment instruments in a digital environment enables comprehensive monitoring of progress, supports active learning, and helps students develop 21st-century competencies—critical thinking, reflection, independence, and digital literacy.

Assessment instruments are no longer merely tools for measuring outcomes; they have become active learning tools, allowing students to track, reflect on, and continuously improve their knowledge and skills.

CHAPTER VII

APPENDICES AND DIGITAL RESOURCES

Modern chemistry teaching relies on a variety of materials and digital resources that support the preparation, delivery, and assessment of the teaching process. Attachments and resources help teachers plan activities, create teaching materials, and integrate digital tools into the classroom, while simultaneously enabling students to engage in active and interactive learning.

OVERVIEW OF DIGITAL TOOLS AND FREE PLATFORMS

Digital tools enable visualization, simulation, and interactive learning of chemical concepts. The most commonly used free platforms include:

PhET Interactive Simulations

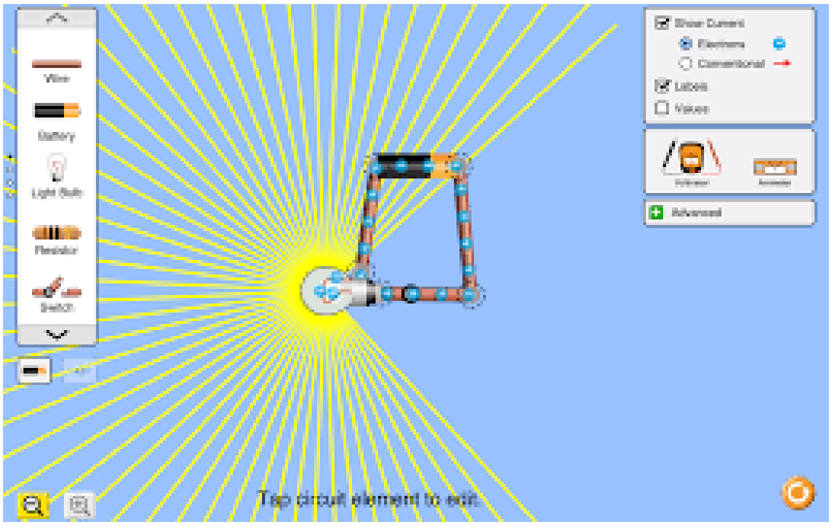


Figure 1. Cover Page of the PhET interactive simulations (source: Wikipedia)

PhET is a free project from the University of Colorado Boulder that offers interactive, inquiry-based simulations in physics, chemistry, biology, geography, and mathematics. The simulations allow students to learn through play and experimentation in a virtual environment, making them particularly suitable for virtual laboratories and for supporting specific lesson units. The project was initiated by Nobel laureate **Carl Wieman**, further emphasizing the quality and research-based nature of the available materials.

Key Features

- All simulations are free, with the option to use online or download for offline use.
- Simulations are developed based on educational research to encourage students to independently explore and discover concepts.
- Tools such as sliders, buttons, and virtual instruments provide immediate feedback and visualize cause-and-effect relationships.
- Simulations cover physics, chemistry, biology, geography, and mathematics, adapted for different educational levels, from primary school to university.
- Some simulations offer audio descriptions, alternative input methods, and translation into over 100 languages, making them accessible.
- Teachers can search and filter simulations, integrate them into their lesson plans, and share materials with colleagues.

Recommendation

PhET simulations are most effective when students actively experiment, formulate hypotheses, and observe results in real time. They enable the visualization of abstract concepts and promote critical thinking and independent learning. Simulations can be used individually, in groups, or as part of integrated lesson activities.

ChemCollective

ChemCollective is a free virtual laboratory that allows the performance of chemical experiment simulations and data analysis in a safe digital environment. This tool is particularly useful for planning and conducting experiments when a physical laboratory is not available or when the focus is on conceptual understanding of processes.

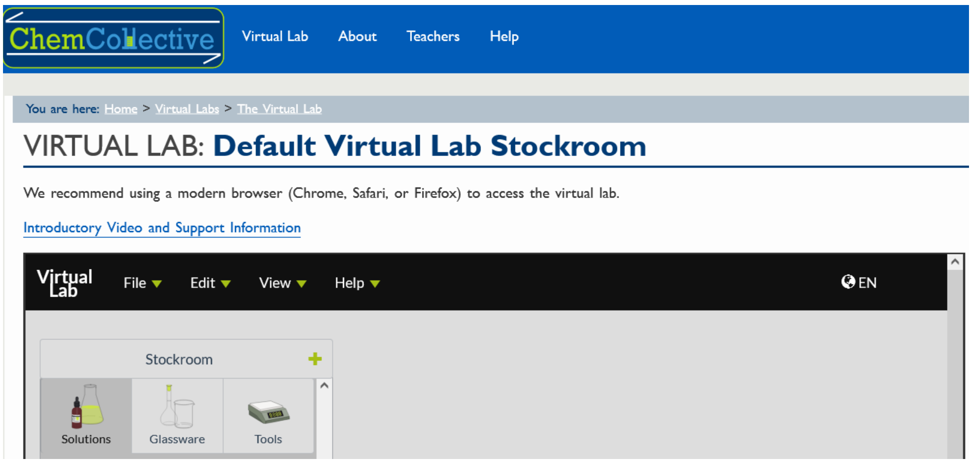


Figure 2. Cover Page of the ChemCollective virtual lab
(source: http://iry.chem.cmu.edu/vlab/vlab.php)

Key Features

- ChemCollective is a virtual laboratory that allows experiments with various chemicals and instruments without the risk of real damage or danger.
- ChemCollective includes prepared tasks, challenges, and inquiry-based simulations suitable for individual and group learning.
- Students can collect and analyze results, create graphs, and draw conclusions, promoting critical thinking.
- Teachers can create their own experiments, monitor student progress, and use the platform for assessment.
- ChemCollective is available online, free of charge, and compatible with various devices.

Recommendation

ChemCollective is most effective when students have prior knowledge of basic chemistry concepts and when the goal is to apply theoretical knowledge in simulated experiments. Active student involvement in planning and analyzing the experiment increases engagement and understanding.

MolView

MolView is a free online tool for 3D visualization of molecules and crystal structures. It allows students and teachers to observe microscopic structures and reactions that are otherwise difficult to see.

Key Features

- 3D molecular visualization: Allows rotation and zooming of molecules, tracking chemical bonds, and spatial orientation of atoms.
- Displays crystal structures, functional groups, and molecular interactions in real time.
- Students can create their own molecules and analyze their characteristics, facilitating the understanding of abstract chemical concepts.
- Works without software installation, compatible with various devices and web browsers.
- Enables easy sharing of visualizations and integration into presentations and online teaching materials.

Recommendation

MolView is an excellent tool for explaining molecular structures, chemical bonds, and stereochemistry. Its visual representations facilitate understanding of complex topics and allow students to connect theory with different models of structural representation. It is recommended to combine it with practical tasks or virtual laboratories to maximize

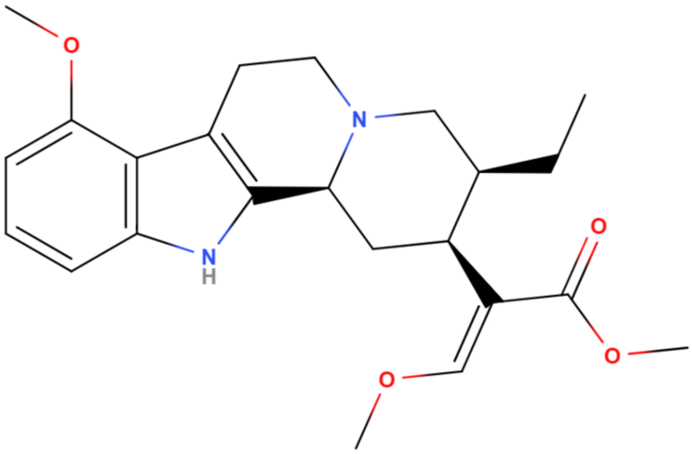


Figure 3. The structure of the alkaloid mitragine was created in the MolView program (source: Wikimedia)

Kahoot, Quizizz, Socrative

These tools allow teachers to create interactive quizzes, surveys, and knowledge games that make the learning process more dynamic and engaging. In addition to their motivational effect, digital quizzes provide immediate feedback, facilitate tracking of student progress, and foster both a competitive and collaborative spirit in the classroom.

Key Features

- Fast and automatic grading of responses.
- Visually engaging, gamified activities (points, time limits, scoreboards).
- Options for individual work or group competition.

- Accessible on mobile devices, enabling easy integration into lessons.
- Result analytics that help teachers identify student difficulties.

Recommendation

Use these tools as a form of formative assessment, especially at the beginning or end of a lesson—to check prior knowledge, summarize the lesson, or conduct a brief self-assessment. Quizzes help engage all students, particularly those less inclined to participate in traditional oral or written tests.

Moodle, Google Classroom, Microsoft Teams

These educational platforms form the foundation for planning, delivering, and monitoring digital lessons. They allow teachers to publish materials, assignments, and quizzes, track student activity, and enable two-way communication. Additionally, the integration of multimedia and digital tools supports more diverse and inclusive learning.

Key Features

- Management of teaching content and resources in one place.
- Digital communication and feedback exchange.
- Assignments, tests, and quizzes integrated within the system.

- Learning analytics: tracking engagement, deadlines, and student performance.
- Support for teamwork and collaboration among students

Recommendation

These platforms should be used to organize and continuously support learning, not just for task administration. It is recommended to structure content into logical modules so that students can understand the connections between topics, and to include diverse formats—text, video, quizzes, forums. This way, the platform serves as a true digital learning environment, rather than just a repository of materials.

Avogadro, Jmol and ChemSketch

These specialized tools are used for drawing, modeling, and visualizing chemical structures and reactions. They enable students and teachers to explore spatial relationships between atoms, analyze types of chemical bonds, and create digital representations of molecules. These tools contribute to a better understanding of abstract and microscopic processes that cannot be easily demonstrated experimentally.

Key Features

- 2D and 3D representations of molecules and crystal structures
- Ability to measure bond lengths, angles, and spatial orientation
- Simulation of molecular rotations and changes in configuration

- Tools for creating reaction mechanisms and formulas
- Free, available for download and use offline

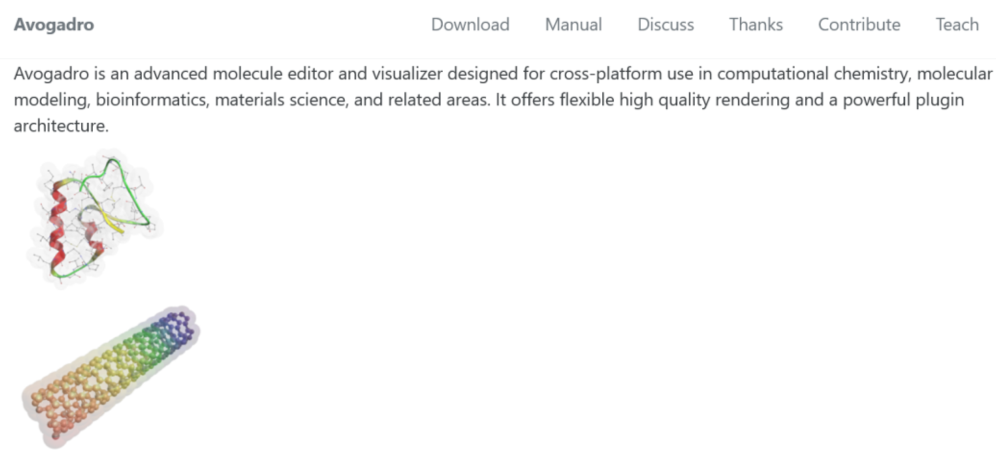


Figure 4. Cover Page of the Avogadro Tool
(source: https://avogadro.cc/)

Recommendation

They can be used in both organic and inorganic chemistry lessons to display and analyze molecules that students draw or investigate themselves. They can also serve for preparing teaching presentations, visualizations in textbooks, or digital materials. It is recommended to integrate these tools with virtual laboratories (e.g., ChemCollective) for a more comprehensive approach to learning.

LESSON PLANNING TEMPLATES

Effective lesson planning forms the foundation of successful and modern chemistry teaching. Lesson planning templates help teachers systematically organize lessons, align learning objectives with activities and assessments, and easily integrate digital tools and multimedia content.

These templates serve as a practical guide, enabling teachers to structure each lesson in accordance with the competencies they aim to develop in students — from experimental and inquiry-based skills to digital literacy and reflective thinking.

Why It Is Important to Plan Lesson Preparations in Advance

- Saves time and facilitates lesson planning.
- Enables a standardized approach within a school or teaching team.
- Simplifies evaluation of the teaching process and sharing of best practices.
- Supports the integration of digital tools, assessment instruments, and student reflection.

🎓 *Example of a Lesson Planning Template Structure*

- **Lesson Unit Title** – Clearly and unambiguously define the lesson topic in accordance with the curriculum.
- **Learning Outcomes** – Precisely list 3–4 concrete outcomes covering knowledge, skills, and attitudes (e.g., the student explains molecular structure, uses a digital modeling tool, and connects theory and practice).
- **Time Frame** – Specify the duration of activities and the temporal structure of the lesson (e.g., 45 or 90 minutes, indicating the duration of each segment).
- **Materials and Digital Resources** – List the required chemicals, equipment, worksheets, and digital tools (e.g., PhET simulation, Kahoot quiz, Avogadro program).
- **Introductory Activities** – Design a motivating start to the lesson that activates prior knowledge and engages students with the topic (e.g., demonstration, question, short video).
- **Main Activities** – Describe the steps and tasks students carry out independently or in groups (experiment, discussion, digital simulation, data analysis).
- **Assessment and Reflection** – Specify methods for evaluating achievement (rubrics, quiz, portfolio) and include reflection questions, such as *What did I learn today?* or *What would I do differently next time?*

Example of a Lesson Preparation Template

Element	**Description / Example**
Lesson Topic	Oxidation and Reduction Reactions
Learning Outcomes	• The student distinguishes between oxidizing and reducing agents; • The student models a redox reaction using a PhET simulation; • The student discusses the role of oxidation in everyday life.
Digital Resource	PhET *Balancing Redox Reactions*
Activities	1. Short discussion (5 min) 2. Experiment / simulation (25 min) Discussion and evaluation (10 min)
Assessment	Quiz in Quizizz + reflection in the digital portfolio

EXAMPLES OF WORKSHEETS

Worksheets are practical tools for guiding activities, self-assessment, and peer assessment. They promote active learning, reflection, and the development of experimental and analytical skills. In chemistry teaching, different types of worksheets can be used depending on the lesson objectives and activity type:

1. ***Experimental Worksheets*** *– used to guide laboratory tasks, plan experiments, and record results.*
2. ***Interactive Worksheets*** *– digital documents that include hyperlinks, quizzes, images, and multimedia content, suitable for online or blended learning.*
3. ***Analytical Tasks*** *– worksheets presenting real-life problem situations, requiring students to apply scientific concepts, analyze data, and draw conclusions.*
4. ***Reflective Worksheets*** *– contain questions for self-assessment and analysis of the learning process after completing an activity or experiment.*

Regardless of the format, worksheets play an important role in developing student independence, fostering inquiry, and supporting formative assessment. They enable students to systematically track their work, record observations, and connect theoretical concepts with practical experience.

A worksheet is recommended to include the following elements:

1. **Worksheet Title** – Clearly indicate the topic or experiment being conducted (e.g., *Investigating the Solubility of Substances in Water*).

2. **Introductory Notes** – Briefly explain the purpose and objective of the activity and pose a guiding research question, e.g., *How does temperature affect the rate of dissolution?*
3. **Materials and Equipment** – List the required chemicals, apparatus, and digital tools (e.g., PhET *Solutions* simulation, thermometer, beakers).
4. **Procedure** – Describe the steps of the experiment or activity that students carry out independently, leaving space for notes or observations.
5. **Results and Observations** – Provide space to record measured values, observations, or drawings.
6. **Analysis and Conclusions** – Guide students to analyze results, connect them with theory, and formulate conclusions in their own words.
7. **Student Reflection** – Include brief questions that encourage self-assessment and critical thinking.

Recommendation

It is advisable to combine worksheets with digital tools (Google Forms, Microsoft Forms, Moodle quizzes) or use interactive PDF forms so that students can enter their answers online. This approach facilitates progress tracking and formative assessment.

Example of Worksheets

<table>
<tr><td>Title</td><td>Testing the solubility of substances in water</td></tr>
<tr><td>Introduction</td><td>In this experiment, students explore how different substances (sugar, salt, baking soda) dissolve in water at room temperature.

The goal is to understand the concept of solubility, the factors that influence it, and to develop skills in maintaining a laboratory record.</td></tr>
<tr><td>Materials</td><td>Water (50 mL per sample)
Sugar, table salt, baking soda
Beakers or test tubes
Measuring spoons or scale
Thermometer
Stirring spoons
Digital tool: PhET Sugar and Salt Solutions simulation (optional)</td></tr>
<tr><td>Procedure</td><td>Pour 50 mL of water into each beaker.
Add a small amount of the chosen substance and stir until it dissolves or the solution becomes saturated.
Record the amount of substance that dissolved.
Repeat for all three substances.
Use the PhET simulation to illustrate intermolecular interactions in the solutions.</td></tr>
<tr><td>Results and Observations</td><td><table><tr><td>Substance</td><td>Mass of solute (g)</td><td>Observations</td></tr><tr><td>Sugar</td><td></td><td></td></tr><tr><td>Salt</td><td></td><td></td></tr><tr><td>Soda</td><td></td><td></td></tr></table></td></tr>
</table>

LITERATURE AND USEFUL LINKS

Resources and materials provide essential support for both teachers and students in modern chemistry teaching. Their use enables effective lesson planning, diverse teaching activities, individualized learning, and active student engagement in the knowledge acquisition process. Well-chosen and structured materials facilitate the integration of digital tools, multimedia content, and artificial intelligence into daily lessons, supporting the development of 21st-century competencies such as critical thinking, digital literacy, and independent learning.

Below is a list of core literature and several online sources that teachers can use as a starting point for independent research, professional development, and enhancement of the teaching process.

Literature

1. Mayer RE. (2009). *Multimedia Learning*. 2nd ed. Cambridge University Press.
2. Holmes, W. (2020). Artificial intelligence in education. In *Encyclopedia of education and information technologies* (pp. 88-103). Cham: Springer International Publishing.
3. *Summaries, C. E. (2019). What Students Know and Can Do. PISA 2009 at a Glance, I, 31*. OECD

Useful Links

PhET Simulations
ChemCollective
OECD Education
UNESCO Open Educational Resources