



METHODOLOGY OF USING DIGITAL INTERACTIVE TOOLS FOR SOLVING CHEMISTRY PROBLEMS

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Abstract: *This methodology outlines a systematic approach to integrating digital interactive tools — molecular visualization software, virtual laboratories, simulations, and computational solvers — into the process of solving chemistry problems. It addresses tool selection, instructional sequencing, scaffolding, and assessment, with the goal of improving both procedural accuracy and conceptual understanding among learners.*

Keywords: *digital didactics, interactive learning, virtual laboratories, chemistry teaching methodology, solving calculation problems, ICT competence, pedagogical experiment.*

Relevance of the Research. The current stage of development of the higher and secondary specialized education system in the Republic of Uzbekistan is characterized by the deep integration of information and communication technologies into all spheres of academic activity. The implementation of the "Digital Uzbekistan – 2030" strategy dictates the need to train specialists capable of not only operating with theoretical knowledge but also effectively utilizing high-tech tools in their professional activities [1].

Chemistry, as a fundamental natural science, possesses a specific complexity associated with the high degree of abstraction of the objects studied. In the learning process, solving chemical problems is traditionally the most labor-intensive stage. This is due to the fact that the student is required not only to have formal knowledge of mathematical formulas but also the ability to multi-levelly represent the

mechanisms of chemical transformations — from macroscopic signs of a reaction to interactions at the atomic-molecular level.

The Research Problem Chemistry problem-solving frequently requires learners to reason about entities and processes that are not directly observable: molecular geometry, electron behavior, reaction kinetics, and equilibrium dynamics. Traditional static media (textbook diagrams, chalkboard equations) often fail to convey the dynamic, three-dimensional, and probabilistic nature of these phenomena. Digital interactive tools address this gap by allowing learners to manipulate variables, visualize structures in real time, and receive immediate feedback.

Purpose. To define a replicable methodology for selecting, sequencing, and evaluating the use of digital interactive tools in chemistry problem-solving, applicable across secondary and higher education contexts.

Scope. This methodology covers:

- Conceptual/qualitative problems (bonding, structure, mechanism)
- Quantitative problems (stoichiometry, equilibrium constants, thermodynamics)
- Procedural/experimental problems (lab technique, safety-constrained reactions)

It does not cover pure computational chemistry research software used at the professional/research level.

Theoretical Framework: The methodology draws on three converging principles:

Principle	Source Discipline	Application
Cognitive Load Theory	Educational Psychology	Tools reduce extraneous load by offloading visualization and calculation

Principle	Source Discipline	Application
Constructivist Learning	Pedagogy	Learners build understanding through manipulation and experimentation
Immediate Feedback Loops	Instructional Design	Real-time correction prevents entrenchment of misconceptions

Classification of Digital Interactive Tools

Tool Category	Examples	Best Suited For
Molecular visualization	Avogadro, ChemDraw, Jmol	Structure, bonding, isomerism, geometry
Virtual laboratories	PhET, Labster, ChemCollective	Procedures, hazardous/costly reactions, technique practice
Dynamic simulations	PhET equilibrium/kinetics sims	Reaction rates, equilibrium shifts, gas laws
Computational solvers	Equation balancers, stoichiometry calculators	Quantitative problem verification
AI-based tutoring systems	Adaptive chemistry tutors	Personalized step-by-step guidance
Gamified platforms	Chemistry quest-style apps	Engagement, formative practice, spaced repetition

Methodology: Stages of Implementation

Diagnostic Assessment: Administer a pre-test or diagnostic task to identify baseline knowledge and common misconceptions (e.g., confusing molarity with molality, or ionic vs. covalent bonding criteria). This determines which tool category is most relevant.

Tool Selection: Match the problem type to the appropriate tool category (see Section 3). Selection criteria include:

- Alignment with the specific misconception or skill gap identified
- Level of interactivity required (passive visualization vs. active manipulation)
- Accessibility and cost constraints of the learning environment

Guided Demonstration: The instructor (or self-paced module) demonstrates the tool's use on a worked example, making the connection between the digital representation and the underlying chemical principle explicit.

Guided Practice: Learners use the tool to solve problems with support available (hints, step reveal, instructor circulation). The tool provides real-time feedback at this stage.

Independent Problem-Solving: Learners attempt problems with reduced tool support, encouraging transfer of understanding from the interactive representation to abstract/symbolic reasoning (e.g., moving from a 3D visualization to a written Lewis structure).

Tool-Assisted Verification: After independent work, learners use the tool to check their solutions, fostering self-correction and metacognitive awareness.

Reflection and Consolidation: Learners articulate, in writing or discussion, how the tool changed their understanding of the problem — distinguishing tool-dependent procedural success from genuine conceptual gain.

Scaffolding Strategy. Scaffolding should be progressive and fading:

High support — full interactivity, guided steps, immediate hints

Moderate support — tool available on request, delayed feedback

Low support — tool used only for final verification

No support — traditional problem-solving, tool withheld to test retention

This fading structure prevents the tool from becoming a permanent crutch and ensures the learner can eventually solve problems without digital assistance.

Assessment and Evaluation . Metrics

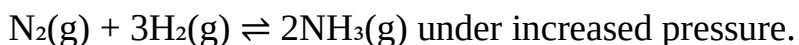
- Accuracy — correctness of final answers, tool-assisted vs. unassisted
- Efficiency — time to solution
- Conceptual retention — performance on delayed post-tests without tool access
- Transfer — ability to apply understanding to novel, untaught problem variants

- Engagement — time-on-task, voluntary tool use, self-reported confidence

Comparative Design: Where feasible, use a control group (traditional instruction only) versus an experimental group (toolintegrated instruction) to isolate the tool's effect, controlling for instructor, content, and time-on-task.

Illustrative Example

Problem type: Predicting the shift in equilibrium position for the reaction:



Applied methodology: Diagnostic: students predict the shift on paper (baseline). Tool: PhET-style equilibrium simulation allowing pressure/volume manipulation. Guided practice: students adjust volume and observe concentration/shift in real time. Independent task: students solve a related problem (temperature change) without the simulation. Verification: students check their prediction against the simulation. Reflection: students explain the reasoning link between Le Chatelier's principle and the observed shift.

Limitations and Considerations

- Access inequity — not all learners have reliable device/internet access.
- Tool over-reliance — risk of procedural fluency without conceptual grounding if scaffolding fails to fade.
- Validation of tool accuracy — simulations must be pedagogically and scientifically validated before adoption.
- Instructor training — effectiveness depends heavily on instructor familiarity with the tool, not just learner exposure.

Conclusion: A structured, staged methodology — diagnostic assessment, deliberate tool selection, guided-to-independent scaffolding, and rigorous evaluation — allows digital interactive tools to meaningfully improve chemistry problem-solving outcomes rather than serving as a novelty supplement. The critical methodological safeguard is the fading support model, which ensures tools build durable understanding rather than substituting for it.

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