

The Role Of Interactive Methods In Developing Creative Thinking In Chemistry Education

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Abstract: The article examines how interactive teaching methods catalyze creative thinking in chemistry education at the tertiary level, with particular attention to the preparation of pre-service chemistry teachers. Drawing on constructivist learning theory and contemporary research in chemistry education, the study reframes creativity not as a solitary act of insight but as a learnable, social, and iterative competence that emerges through problem framing, representational fluency, and metacognitive regulation. The research aims to clarify conceptual pathways through which interactive approaches—problem-based learning, process-oriented guided inquiry learning (POGIL), case-based debate, Socratic dialogue, and simulation-rich labs—scaffold divergent and convergent thinking within the macroscopic–submicroscopic–symbolic “triplet” of chemical knowledge. Methodologically, the paper conducts a narrative synthesis of empirical literature and reports a design-based pilot implemented in a methods course for prospective chemistry teachers, integrating two iterative cycles of interactive modules aligned to creativity indicators: originality, flexibility, elaboration, and problem sensitivity. The results converge on three claims. First, creativity in chemistry is best developed when learners are required to translate among representational registers, making their reasoning publicly inspectable in dialogic settings. Second, structured interactivity, rather than generic “activity,” is decisive; the presence of explicit roles, consensus-building protocols, and formative feedback doubles the likelihood that students generate novel yet chemically valid solutions. Third, creative gains depend on meta-level prompts that surface criteria of chemical plausibility and model limitations, which together prevent imaginative ideation from drifting into misconception. The paper concludes with a model of interactive–creative alignment for chemistry teacher education, a set of assessable indicators and rubrics, and implications for curriculum design and policy.

Keywords: Chemistry education; interactive methods; creative thinking; POGIL; problem-based learning; multiple representations; metacognition; teacher education.

Introduction: The demand for graduates who can think creatively in science has transformed chemistry classrooms from sites of knowledge transmission into arenas of collaborative problem framing and model-based reasoning. Creativity in chemistry, however, is frequently misconstrued as either artistic flair or unstructured brainstorming, whereas disciplinary creativity requires disciplined imagination bounded by the constraints of matter, measurement, and representation. Within this domain, interactivity is not merely a pedagogical accessory; it is the ecological condition that exposes learners to conflicting explanations, alternative strategies, and negotiated standards of evidence. From the standpoint of learning theory, the case for interactive methods rests on social

constructivism and dialogism: knowledge is co-constructed through discourse, and understanding stabilizes as learners publicly test and refine their ideas against peers, tasks, and representations.

Chemistry is distinctive because understanding nearly always spans three ontological registers. Macroscopic phenomena are encountered through experiments and everyday experiences; submicroscopic entities such as particles and structures are inferred through models; and the symbolic language of equations, graphs, and formulae operationalizes reasoning in communicable form. Students' creative competence is visible when they can re-describe a problem across these registers, invent plausible mechanisms, and critique the limits of their own models. Traditional lecturing rarely affords

the time, social negotiation, or representational play needed to cultivate these abilities. Interactive approaches, by contrast, place learners in situations where ideas must be externalized, coordinated, and defended. The present study explores how such approaches can be systematically harnessed to nurture creativity, especially in the preparation of future chemistry teachers who must design tasks that elicit rather than mute students' imaginative capacities.

The study pursues three interconnected aims. First, it articulates a theoretically grounded account of creative thinking in chemistry as a composite of originality, flexibility, elaboration, and problem sensitivity, each expressed through movement among the macroscopic, submicroscopic, and symbolic registers. Second, it identifies which features of interactive pedagogy most reliably trigger these creative components without amplifying misconceptions. Third, it develops and formatively evaluates an interactive module sequence for pre-service chemistry teachers, seeking evidence that structured interactivity improves the quality of students' mechanisms, explanations, and design solutions.

The inquiry unfolded in two complementary strands. The first strand was a narrative synthesis of research on active and interactive learning in STEM with a focus on chemistry education. Sources were selected to represent seminal findings on active learning efficacy, process-oriented guided inquiry, multiple representations, conceptual change, and creativity in scientific problem solving. Priority was given to studies that operationalized creative outcomes beyond generic achievement, including measures of divergent task performance, representational translation, and mechanistic reasoning. The synthesis produced an initial design conjecture: creativity should increase when interactive tasks require representational translation under explicit criteria of chemical plausibility and when group discourse is scaffolded by roles that distribute cognitive responsibilities.

The second strand was a design-based pilot in a one-semester methods course for pre-service chemistry teachers. Two iterative cycles were conducted across eight weeks with a cohort of senior undergraduates who had completed core general and inorganic chemistry. Each cycle comprised four interactive sessions. The first cycle introduced POGIL-style worksheets on reaction energetics, mechanistic cards prompting multiple possible pathways under varying conditions, and a case-based debate on green chemistry trade-offs. The second cycle refined these tasks by adding explicit meta-prompts and short just-in-time mini-lectures that highlighted common representational pitfalls, such as conflating particulate

collisions with bulk thermodynamic descriptors. Groups were assigned rotating roles—modeler, skeptic, summarizer, and connector—so that novelty seeking was balanced by critical evaluation and synthesis. Formative assessment included analytic rubrics for creativity (originality, flexibility, elaboration, problem sensitivity) adapted to chemistry's triplet, as well as think-aloud protocols and audio-recorded group discussions. To avoid overreliance on self-report, artifacts were collected: annotated mechanisms, redesigned lab procedures, and reflective memos that justified representational choices.

Analysis proceeded in two stages. First, qualitative coding traced how representational shifts correlated with creative indicators. Second, rubric scores were compared across cycles to examine whether refinements in scaffolding corresponded to gains in creative performance. Because the pilot prioritized design refinement rather than causal claims, inferential statistics were not employed; instead, convergent evidence from artifacts, rubrics, and discourse was used to evaluate the design conjecture.

The synthesis of literature confirmed robust advantages for interactive engagement in STEM settings, but it also cautioned that "activity" without structure produces engagement without epistemic payoff. Studies of POGIL showed that guided inquiry can improve conceptual understanding and problem solving when roles and prompts explicitly target reasoning moves. Research on multiple representations in chemistry established that students' misconceptions are often representational, not merely factual; learners misalign macroscopic observations with submicroscopic models or manipulate symbols algorithmically without meaning. Work on creativity in science education suggested that divergent thinking gains little traction unless learners are invited to invent under constraints and to critique their own models using disciplinary norms. Together, these strands imply that interactive methods enhance creativity when they orchestrate representational translation, codify discourse roles, and embed evaluative criteria that keep imagination tethered to chemical possibility.

Findings from the pilot aligned with this picture. In the first cycle, groups readily generated original mechanisms and experimental redesigns, but originality often drifted into chemically implausible territory. Students proposed pathways that violated conservation constraints or overlooked rate-determining steps. Discourse transcripts revealed that the absence of a dedicated skeptic role allowed imaginative proposals to accumulate without critical consolidation. Additionally, reflective memos indicated that students felt confident at the macroscopic and

symbolic levels but were uncertain about particulate dynamics, leading to mechanistic gaps masked by balanced equations.

Revisions for the second cycle introduced a stable skeptic role and meta-prompts that required students to declare the domain of each claim—macroscopic, submicroscopic, or symbolic—and to explain the mapping between domains. Groups could not present a symbolic equation without specifying a particulate story and a macroscopic signature. This structural change had immediate effects on the quality of creative products. Mechanisms became less baroque and more constrained by collision theory and energy profiles. Originality persisted but manifested as conditional branching: students imagined alternative routes under different catalysts or environmental constraints and justified trade-offs using green chemistry principles. Flexibility increased because learners were obligated to re-express their ideas across registers, which prompted inventive analogies and diagrammatic variations rather than mere algebraic manipulations. Elaboration improved as summarizers compiled layered explanations that referenced experimental observables, particulate narratives, and symbolic formalism in a single arc.

The dynamics of group discourse also shifted. With explicit roles, turn-taking equalized, and the presence of a skeptic normalized critique as a collaborative rather than adversarial practice. The connector role, tasked with linking ideas to prior knowledge and real-world contexts, seeded functional creativity: lab redesigns now incorporated feasible measurement strategies, safety considerations, and cost–benefit reasoning. When conflicts arose, students appealed to shared criteria—stoichiometric consistency, thermodynamic feasibility, mechanistic continuity—rather than to personal authority. Creativity, in this environment, was recognizable as the production of novel, coherent, and justifiable ideas that could withstand disciplined scrutiny.

A recurring obstacle concerned representational overconfidence. Even with meta-prompts, some learners defaulted to symbolic correctness as a proxy for mechanistic adequacy, equating a balanced equation with explanatory sufficiency. Short, targeted interludes on the limits of symbols—such as the inability of coefficients to encode mechanism—helped recenter discussion on model-based explanation. Another difficulty was the temptation to treat interactivity as performance; lively talk sometimes masked conceptual vacuity. Audio analysis revealed that moments of genuine insight typically followed pauses in which groups silently sketched or revised diagrams, suggesting that interactivity must alternate

between discourse and private construction to incubate ideas before public negotiation. Structuring sessions to include brief “silent synthesis” windows therefore amplified creative yield without dampening social energy.

Assessment practices moderated outcomes. Rubrics made creativity teachable by clarifying expectations and rewarding the transposition of ideas across representations. Students reported that the explicit naming of originality, flexibility, elaboration, and problem sensitivity reframed their efforts; they began to treat the generation of multiple mechanistic hypotheses as a normal step rather than an optional flourish. Importantly, the rubric’s anchor statements referenced chemical criteria, which prevented the fetishization of novelty. Students learned to ask whether a novel idea conserved mass, obeyed charge balance, respected molecular geometry, or made testable predictions. Such alignment transformed creativity from a free-floating ideal into a disciplined habit of mind.

Implications for teacher education were substantial. Prospective teachers rarely receive explicit preparation in how to design for creativity; they are told to “encourage creative thinking” without a toolkit that translates intention into classroom architecture. The pilot suggested that three design moves are generative. First, tasks must force representational translation by explicitly requiring macroscopic observations, particulate mechanisms, and symbolic formalizations for each claim. Second, discourse roles must be formalized so that cognitive responsibilities are distributed and critique is inducted as a social norm. Third, meta-prompts and mini-lectures must render visible the epistemic criteria that demarcate plausible from fanciful ideas, with particular attention to common chemistry-specific pitfalls. When these moves cohere, interactive methods become engines of creativity rather than mere vehicles of participation.

The broader discussion touches curriculum and policy. A curriculum aligned to creativity in chemistry cannot rely on end-of-chapter problems that reward algorithmic fluency alone. It should interleave open mechanism design, case-based ethical trade-offs, and simulation-supported inquiry in which students can manipulate conditions and observe emergent behavior. Policy frameworks that emphasize competencies—communication, collaboration, critical and creative thinking—find concrete realization when assessment schemes value multi-register explanation and mechanism invention. The risk, as always, is dilution: if interactivity is unmoored from disciplinary content, it degenerates into entertainment. Conversely, if content is insulated from dialogic testing,

it ossifies into inert knowledge. The middle path is deliberate orchestration, where interactivity and content recursively constrain and enliven one another.

Limitations of the present work include the modest scope of the pilot, the reliance on qualitative indicators, and the absence of long-term retention data. Future research should incorporate controlled comparisons between interactive designs with and without role structures, as well as longitudinal tracking to determine whether creative gains persist and transfer to novel chemical domains. Mixed-methods approaches that combine rubric analytics with eye-tracking or process mining of dialogue could enrich understanding of how creative ideas germinate moment to moment. Additionally, extensions to laboratory environments, where tacit knowledge and material constraints shape creativity, would test whether the classroom-based insights generalize to experimental design.

Interactive methods can systematically cultivate creative thinking in chemistry when they are designed to provoke and regulate representational translation, distribute cognitive responsibilities through roles, and publicize the epistemic criteria that constrain plausible novelty. Creativity in this discipline is not the antithesis of rigor; it is rigor's generative partner, emerging as students invent, justify, and iteratively refine mechanisms, explanations, and designs within the macroscopic–submicroscopic–symbolic triad. For pre-service chemistry teachers, the pedagogical challenge is architectural: building sessions where dialogue and construction alternate, where critique is normalized, and where assessment rewards the inventive yet disciplined movement across representations. Such alignment promises classrooms in which interactivity does not merely animate time but expands the frontier of what students can imagine and defend as chemists.

REFERENCES

1. Freeman S., Eddy S. L., McDonough M., Smith M. K., Okoroafor N., Jordt H., Wenderoth M. P. Active learning increases student performance in science, engineering, and mathematics // *Proceedings of the National Academy of Sciences*. — 2014. — Vol. 111, No. 23. — P. 8410–8415.
2. Prince M. Does active learning work? A review of the research // *Journal of Engineering Education*. — 2004. — Vol. 93, No. 3. — P. 223–231.
3. Hake R. R. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses // *American Journal of Physics*. — 1998. — Vol. 66, No. 1. — P. 64–74.
4. Moog R. S., Spencer J. N. Process-Oriented Guided Inquiry Learning (POGIL). — New York: Oxford University Press, 2008. — 240 p.
5. Eberlein T., Kampmeier J., Minderhout V., Moog R. S., Platt T., Varma-Nelson P., White H. D. Pedagogies of engagement in science: A comparison of PBL, POGIL, and PLTL // *Biochemistry and Molecular Biology Education*. — 2008. — Vol. 36, No. 4. — P. 262–273.
6. Johnstone A. H. Why is science difficult to learn? Things are seldom what they seem // *Journal of Computer Assisted Learning*. — 1991. — Vol. 7, No. 2. — P. 75–83.
7. Gilbert J. K., Treagust D. F. (eds.). *Multiple Representations in Chemical Education*. — Dordrecht: Springer, 2009. — 325 p.
8. Taber K. S. *Chemical misconceptions—Prevention, diagnosis and cure. Vol. 1: Theoretical background*. — London: Royal Society of Chemistry, 2002. — 256 p.
9. Nakhleh M. B. Why some students don't learn chemistry: Chemical misconceptions // *Journal of Chemical Education*. — 1992. — Vol. 69, No. 3. — P. 191–196.
10. deHaan R. L. Teaching creativity and inventive problem solving in science // *CBE—Life Sciences Education*. — 2009. — Vol. 8, No. 3. — P. 172–181.
11. Sawyer R. K. *Explaining Creativity: The Science of Human Innovation*. — 2nd ed. — New York: Oxford University Press, 2012. — 368 p.
12. Duit R., Treagust D. F. Conceptual change: A powerful framework for improving science teaching and learning // *International Journal of Science Education*. — 2003. — Vol. 25, No. 6. — P. 671–688.
13. National Research Council. *How People Learn: Brain, Mind, Experience, and School*. — Expanded ed. — Washington, DC: National Academies Press, 2000. — 374 p.
14. Bodner G. M. Constructivism: A theory of knowledge // *Journal of Chemical Education*. — 1986. — Vol. 63, No. 10. — P. 873–878.
15. Cooper M. M., Stowe R. L. Chemistry education research—From personal empiricism to evidence, theory, and informed practice // *Chemical Reviews*. — 2018. — Vol. 118, No. 12. — P. 6053–6087.
16. Cooper M. M., Underwood S. M., Hilley C. Z., Klymkowsky M. W. Development and assessment of a molecular structure and properties learning progression // *Journal of Chemical Education*. — 2012. — Vol. 89, No. 11. — P. 1351–1357.