A Case Study of a Blended and Personalized Instructional Framework for Core Quantitative Experiments in Secondary School Chemistry

Mingchao Miao, Shiwei Lin*, Zihan Yu

Changchun Normal University, Chemistry College, Changchun, China
*Corresponding author. Email: linswchem@163.com

Abstract. Senior high school chemistry laboratory teaching often relies on uniform procedures that do not adequately respond to learner differences, while many blended-learning practices remain at the level of resource addition rather than instructional integration. Focusing on two representative quantitative experiments - solution preparation and acid-base titration - this paper develops a three-dimensional framework through literature analysis, curriculum interpretation, and framework-to-case mapping. The framework integrates tiered resource construction, differentiated inquiry task design, and a process-oriented assessment loop. The analysis suggests that the framework is aligned with curriculum standards, compatible with the disciplinary logic of quantitative experiments, and feasible under ordinary school conditions. Rather than claiming completed large-scale effectiveness verification, the study offers a cautious and transferable design reference for subsequent classroom implementation and empirical testing.

Keywords: Blended learning, Personalized teaching, Senior high school c-hemistry, Laboratory instruction, Quantitative experiments, Instructional framework

1 Introduction

The General Senior High School Chemistry Curriculum Standards (2017 Edition, 2020 Revision) emphasize that laboratory teaching is a key vehicle for developing disciplinary core competencies [1]. In senior high school chemistry, solution preparation and acid-base titration are representative core quantitative experiments because they combine standardized operation, numerical reasoning, and error analysis. Yet ordinary school practice still faces three tensions: uniform teaching sequences often privilege procedural imitation; online resources are frequently detached from classroom tasks; and assessment still focuses more on final correctness than on process evidence and transfer.

Existing studies have separately discussed blended learning, tiered instruction, and laboratory improvement, but fewer studies provide a transferable framework that connects resources, tasks, and assessment across both compulsory and selective-compulsory experiments. This gap is especially visible in quantitative experi-

B. Kanoksilapatham et al. (eds.), *Proceedings of the 2026 2nd International Conference on Education Reform, Ideology and Politics (ERIP 2026)*, Advances in Social Science, Education and Humanities Research 1028,
https://doi.org/10.2991/978-2-38476-601-7_15

ments, where operational precision and conceptual understanding must be coordinated within limited class time.

To address this issue, this paper constructs a blended and personalized teaching framework and argues for its plausibility through two representative cases. The study contributes by translating broad ideas about blended learning and personalization into an operable laboratory design logic, demonstrating transferability across two core experiments, and explicitly separating framework argumentation from later empirical verification.

2 Literature Review and Theoretical Basis

Blended learning should be understood as purposeful integration rather than simple addition of online activities to face-to-face teaching [2]. In chemistry laboratories, micro-lessons, simulations, and digital recording tools can support pre-class rehearsal, risk identification, and rapid feedback, but their value depends on whether they are linked to classroom goals and post-class reflection.

Personalized laboratory teaching requires more than providing extra materials. Learner differences commonly appear in understanding of principles and apparatus, precision in key operations, and willingness to engage in error analysis. Therefore, effective differentiation should adjust supports, task depth, and feedback pathways on the basis of observable learning evidence rather than rigid student labeling [3].

The framework draws mainly on mastery learning [4], connectivism [5], and alignment-oriented design. Mastery learning supports the combination of minimum attainment and layered advancement; connectivism explains how learning can continue through digital resources and feedback nodes; and alignment theory clarifies why goals, tasks, and assessment evidence must be coherently connected [6].

3 Research Design, Questions, and Analytical Criteria

This paper is a framework-construction and case-based argumentation study rather than a large-sample effectiveness evaluation. Its central question is whether a blended and personalized framework for core quantitative experiments can be constructed in a logically defensible and instructionally usable way.

The study proceeds in three steps. First, literature on blended learning, chemistry laboratory teaching, and differentiated instruction was reviewed to identify design variables such as resource type, task structure, and feedback pathway. Second, curriculum standards and textbook requirements were interpreted to clarify common features of quantitative experiments, including procedural accuracy, safety, evidence-based analysis, and transfer. Third, the framework was mapped onto two representative experiments to test internal coherence and classroom plausibility.

Three analytical criteria were adopted: goal alignment with curriculum requirements, disciplinary compatibility with the logic of quantitative experiments, and implementation feasibility under ordinary school conditions. These criteria provide a cautious basis for argumentation but do not replace later empirical validation.

4 Construction of the Blended and Personalized Teaching Framework

The framework follows five principles: competency orientation, safety first, light-weight implementation, responsiveness to learner differences, and integration of teaching, learning, and assessment. Together these principles ensure that digital resources are used for diagnosis and support rather than for superficial enrichment.

The first dimension is tiered construction of laboratory resources. Core resources cover apparatus recognition, key operations, safety prompts, and common errors, while extended resources provide corrective, explanatory, and transfer-oriented materials. The second dimension is differentiated inquiry task design across pre-class rehearsal, in-class practice, and post-class transfer. Students may move across support levels according to rehearsal results and classroom performance rather than fixed grouping.The third dimension is a process-oriented assessment loop. Experimental portfolios collect rehearsal records, observation sheets, calculation notes, error-analysis entries, and reflection logs so that assessment can focus on operational accuracy, evidence interpretation, and transfer application instead of only the final answer.

For a clearer demonstration of the interconnection among the three dimensions, Figure 1 shows the three-dimensional interactive design model of the framework.

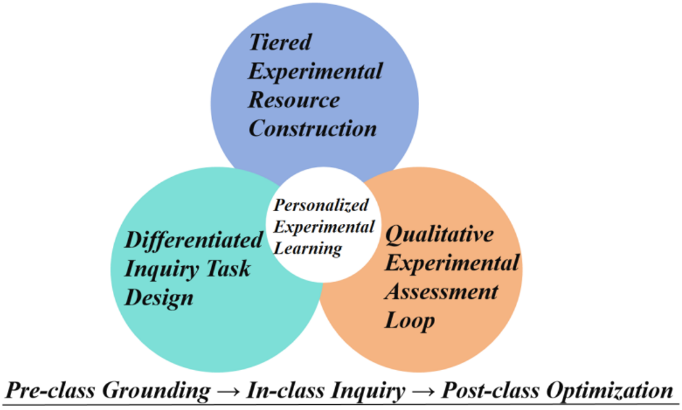

Fig. 1. Three-Dimensional Interactive Design Model of Personalized Chemistry Experimental Teaching in Senior High School under Blended Learning

To operationalize the three dimensions, the framework relies on a set of light-weight digital tools that are commonly accessible in ordinary school settings. For the tiered resource dimension, learning management system (LMS) modules or shared cloud folders can host micro-lesson videos, virtual simulation links, and printable error-checklists, allowing students to access materials that match their readiness levels before and after class. For the differentiated inquiry dimension, in-class response systems (e.g., mini-whiteboards or polling apps) enable teachers to collect real-time evidence of student understanding and adjust task allocation dynamically. For the process-oriented assessment dimension, digital portfolios or simple e-forms facilitate the documentation of rehearsal records, observation notes, and reflection logs, making the assessment loop practical without adding excessive paperwork. These tools are not intended to replace hands-on experimentation or teacher-student interaction; rather, they serve as low-cost scaffolds that make tiered resource delivery, real-time differentiation, and evidence-based assessment feasible within the constraints of regular laboratory periods.

5 Case-Based Argumentation in Two Core Quantitative Experiments

In solution preparation, students must master dissolving, transferring, washing, fixing volume, and mixing while understanding how each step affects concentration accuracy. Under the proposed framework, pre-class rehearsal uses micro-lessons and simulation to identify common mistakes such as inappropriate flask selection or inaccurate meniscus reading. In class, all students complete the standard task, but extensions differ: foundational learners consolidate operating norms, intermediate learners compare how specific errors influence results, and advanced learners design a small inquiry about factors affecting concentration accuracy.

Between the two cases, a noteworthy distinction lies in their cognitive and operational demands. Solution preparation emphasizes procedural sequencing and volumetric accuracy, where most errors arise from transfer loss and meniscus misreading; these are relatively concrete and can be effectively rehearsed through simulation and checklists. Acid-base titration, by contrast, involves dynamic endpoint judgment, data series processing, and multiple error sources such as burette reading, indicator selection, and bubble removal. This added complexity requires not only procedural fluency but also real-time decision-making, which implies that the framework's tiered resources and differentiated tasks need to be calibrated differently for the two experiments. For the simpler solution preparation, foundational supports may focus on rule reinforcement and error recognition, whereas for titration, even foundational learners benefit from stronger emphasis on why errors occur and how to judge data validity. Similarly, advanced tasks in the former might explore alternate glassware choices, while in the latter they might involve optimizing a titration strategy or discussing its relevance to environmental or pharmaceutical contexts. This comparison suggests that the framework is not a rigid template but a flexible design logic: it retains the same three-dimensional structure across experiments, yet allows the difficulty, specificity, and openness of each layer to be tailored to the unique features of the targeted quantitative task.

In acid-base titration, students need to coordinate burette use, endpoint judgment, data recording, and numerical reasoning. Before class, simulation supports repeated identification of endpoint color change and residual-bubble errors. During the lesson, all students complete one standard titration, while differentiated tasks ask learners to compare reading differences, judge data validity, or discuss how a titration strategy should be optimized in a new scenario.

Although the two experiments differ in knowledge difficulty and operational complexity, both can be organized within the same framework. In each case, pre-class rehearsal reduces risk, in-class differentiated tasks accommodate learner diversity, and process-based assessment supports richer error analysis. This does not prove final effectiveness, but it indicates that the framework captures a transferable meso-level design logic worthy of later classroom testing. Table 1 provides a concrete example of how tiered tasks can be arranged for these experiments across pre-class, in-class, and post-class stages.

Table 1. Sample of tiered blended tasks for core quantitative experiments.

Learning stage	Foundational support tasks	Progressive inquiry tasks	Open transfer tasks
Pre-class rehearsal	Watch the micro-lesson and complete a virtual rehearsal; record likely errors.	Compare outcome differences caused by alternative operations.	Raise one question for rehearsal and draft a brief inquiry plan.
In-class practice	Complete the standard experiment with an observation checklist.	Add one comparison task, such as reading or endpoint effects on results.	Optimize the procedure or discuss a new quantitative scenario based on class data.
Post-class transfer	Complete the portfolio and write a brief reflection on errors.	Explain data deviation and propose improvement strategies.	Transfer the method to a real-life context in a short report.

6 Discussion, Boundaries, and Suggestions

Compared with the traditional sequence of lecturing, doing, and submitting a report, the framework has three practical merits. It turns online resources into diagnostic tools before laboratory entry, transforms the lesson from single-path training into progressive inquiry, and expands assessment from result judgment to evidence-based documentation of the learning process. This position is review-safe because it argues for plausibility and instructional value without overstating causal proof.

Beyond these practical merits, the effective implementation of this framework also imposes new demands on teachers' instructional design competence and classroom orchestration skills. In traditional laboratory sessions, teachers primarily serve as demonstrators of standard procedures and judges of final results. Under the proposed framework, however, they must simultaneously act as resource curators, differentiated task facilitators, and interpreters of process-based assessment evidence. This role expansion entails extra workload before class, such as selecting or producing tiered micro-lessons and designing flexible task cards, as well as heightened alertness during class to identify individual students' operational difficulties and adjust scaffolding in real time. Moreover, while tiered tasks accommodate learner diversity, they may introduce complexity in time management and group interaction, especially when students at different support levels work concurrently in the same laboratory. Therefore, a critical practical question concerns how to balance the benefits of personalization against the costs of increased instructional complexity, and how to prepare teachers with adequate professional development and manageable resource support before the framework is scaled beyond pilot settings.

The study has clear boundaries. It proposes a theoretical framework rather than a mature model validated through large-scale implementation. Its direct applicability is strongest for experiments with relatively clear operational sequences and strong value for quantitative error analysis; more open-ended project work may require adaptation.

Follow-up research can proceed in three directions: small-scale classroom implementation using observation, portfolios, and reflective writing; development of modular resource packages and assessment tools for additional core experiments; and exploration of AI-assisted learning analytics to identify frequent rehearsal errors and generate timely feedback.

7 Conclusion

Focusing on solution preparation and acid-base titration, this paper constructs a blended and personalized teaching framework composed of tiered resource construction, differentiated inquiry task design, and a process-oriented assessment loop. The analysis suggests that the framework can connect curriculum requirements, disciplinary logic, and ordinary school conditions in a relatively stable way.

More importantly, it offers a cautious but transferable design reference showing how blended resources can function as part of diagnosis, support, inquiry, and feedback rather than as peripheral supplements. Its substantive classroom effectiveness remains a task for follow-up empirical research.

Disclosure of Interests

The author declares no competing interests relevant to the content of this paper.

Funding

This work was supported by the Graduate Innovation Project of Changchun Normal University (Grant No. YJSCX2026025).

References

1. Ministry of Education of the People's Republic of China: General Senior High School Chemistry Curriculum Standards (2017 Edition, 2020 Revision). People's Education Press, Beijing (2020). https://www.pep.com.cn/xw/zt/rjwy/gzkb2020/.
2. Sharma, P. (2010). Blended learning. ELT journal, 64(4), 456-458. DOI:10.1093/elt/ccq043.

3. Suprayogi, M. N., Valcke, M., & Godwin, R. (2017). Teachers and their implementation of differentiated instruction in the classroom. Teaching and teacher education, 67, 291-301. DOI: 10.1016/j.tate.2017.06.020.
4. Block, J. H., & Burns, R. B. (1976). Mastery learning. Review of research in education, 4, 3-49. DOI: 10.3102/0091732X004001003.
5. Mukhlis, H., Haenilah, E. Y., Maulina, D., & Nursafitri, L. (2024). Connectivism and digital age education: Insights, challenges, and future directions. Kasetsart Journal of Social Sciences, 45(3), 803-814. DOI: 10.34044/j.kjss.2024.45.3.11.
6. Xie, C. X. (2025). Exploration of the path of integrating tiered teaching and teaching-learning-assessment integration in senior high school chemistry experiments: A case study of the teaching of "Preparation and properties of chlorine". In Proceedings of the 5th Academic Symposium on Innovation and Development of Educational Information Technology (pp. 709-712). Anxiang County Institute of Educational Research, Hunan Province. DOI: 10.26914/c.cnkihy.2025.038681.