IMPROVING PROFESSIONAL AND METHODOLOGICAL READINESS OF FUTURE BIOLOGY TEACHERS THROUGH SCHOOL-BASED PRACTICE

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ABSTRACT

This article examines how structured school-based practice can improve the professional and methodological readiness of future biology teachers. Drawing on the theoretical foundations of pedagogical content knowledge, experiential and situated learning, and practice-based teacher education, the study proposes and analyzes a design-based methodology that integrates mentored lesson design, inquiry-rich classroom enactment, iterative reflection, and evidence-informed feedback. The methodology was developed over three iterative cycles with cohorts of pre-service biology teachers during their practicum. Multiple data sources were used for formative evaluation, including lesson plans, classroom video excerpts, mentor observation rubrics, reflective journals, and assessment artifacts such as student work and item analyses. The analysis focused on five readiness dimensions central to biology teaching: planning for conceptual change and inquiry, enacting investigations and fieldwork with attention to safety and ethics, formative assessment for learning, classroom discourse and explanation, and reflective decision-making informed by learner evidence. Results indicate consistent growth in the specificity and coherence of lesson plans, more accurate alignment of learning objectives with assessment tasks, richer use of scientific practices, and an increased capacity to anticipate and address common biological misconceptions. Mentoring quality and school resource constraints emerged as pivotal contextual factors, and the integration of digital tools contributed to better feedback loops when those tools were purposefully aligned to pedagogical goals. The article concludes that school-based practice, when framed as an iterative, mentored, evidence-seeking process rather than a single placement, substantially strengthens professional-methodological readiness and offers a replicable model for biology teacher education programs. Implications for program design include strengthening university–school partnerships, codifying observation and feedback protocols grounded in disciplinary practices, and building assessment literacy that links classroom evidence to instructional adjustments.

KEYWORDS: School-based practice; biology teacher education; professional readiness; methodological competence; PCK; inquiry-based learning; formative assessment; reflective practice; TPACK.

INTRODUCTION

Preparing future biology teachers requires more than exposure to educational theory or subject-matter coursework; it demands the cultivation of professional judgment and methodological fluency in authentic school contexts. The longstanding “theory–practice” gap often surfaces when novices struggle to translate canonical ideas such as inquiry-based learning, conceptual change, or formative assessment into coherent lessons and responsive teaching moves. In biology, this gap can be magnified by the experimental and field-oriented nature of the discipline, the prevalence of entrenched misconceptions about living systems, and the logistical demands of laboratory safety, ethical specimen use, and data-rich investigations. Building professional and methodological readiness therefore hinges on giving candidates structured opportunities to plan, enact, and analyze instruction while supported by mentors who make disciplinary reasoning visible.

The literature highlights several converging lenses for such preparation. Pedagogical content knowledge draws attention to the specialized ways teachers represent core ideas, diagnose misconceptions, and sequence tasks so that learners can appropriate disciplinary practices rather than merely memorize facts (Shulman, 1986; Magnusson, Krajcik, & Borko, 1999). Experiential and situated learning emphasize that professional knowledge is enacted and refined in practice through legitimate participation in the community of teachers, not only acquired in university courses (Kolb, 1984; Lave & Wenger, 1991). Reflective practice and the turn to practice-based teacher education argue that novices learn to teach by approximating core instructional routines, receiving targeted feedback, and engaging in disciplined reflection with artifacts of their own teaching (Schön, 1983; Grossman, Hammerness, & McDonald, 2009). In science education specifically, reform frameworks call for engaging learners in scientific practices such as modeling, argument from evidence, and data analysis in ways that connect crosscutting concepts with disciplinary core ideas (National Research Council, 2012; NGSS Lead States, 2013). Translating these insights into a workable methodology for school-based practice is the central concern of this article.

The context that motivates this study is typical of many teacher education systems: candidates complete discipline courses, methods seminars, and a limited practicum, but report difficulty aligning objectives, activities, and assessment; struggle to orchestrate classroom discourse around scientific explanations; and underuse formative evidence in lesson adaptation. Mentor observations, while helpful, can be uneven and insufficiently anchored to disciplinary practices. Digital tools are often adopted for convenience rather than as mediators of inquiry or feedback. To address these issues, we designed and analyzed a school-based practice methodology that explicitly integrates inquiry-rich planning, mentored enactment, structured reflection, and evidence-informed feedback cycles. Our intent is not only to argue for school-based practice but to specify how its design features can reliably strengthen readiness in biology.

The study aims to develop and examine a school-based practice methodology that improves the professional and methodological readiness of future biology teachers. Specifically, it seeks to determine how iterative, mentored cycles of planning, enactment, and reflection affect five readiness dimensions—disciplinary planning, inquiry enactment with safety and ethics, formative assessment, discourse and explanation, and evidence-informed reflection—and to surface contextual conditions that support or hinder growth in these areas.

The research employed a design-based approach over one academic year with two cohorts of pre-service biology teachers during their school practicum. The methodology was co-designed by university methods instructors and experienced school mentors and implemented in three iterative cycles aligned with practicum milestones. Each cycle included a methods seminar focused on a specific set of practices, a lesson planning phase using a structured template, classroom enactment with mentor observation, and post-lesson reflection anchored in artifacts such as annotated plans, student work samples, and short video segments.

Participants engaged in mentored planning where they identified target core ideas and anticipated prevalent misconceptions, selected investigations or modeling tasks that could elicit student reasoning, and mapped formative checks aligned to the learning goals. Safety and ethical considerations were made explicit, including risk assessments for laboratory setups and guidelines for live or preserved specimens. Digital tools were introduced only when they afforded disciplinary practices, for example, using data loggers for respiration investigations or video for slow-motion analysis of plant movement, and when they could capture formative evidence efficiently.

Data sources for formative evaluation included lesson plans scored with a rubric operationalizing the five readiness dimensions, classroom observations recorded on a structured protocol emphasizing discourse moves and the use of evidence, reflective journals written after each cycle, and collections of student work analyzed for alignment, cognitive demand, and feedback quality. In addition, pre- and post-practicum self-efficacy measures for key biological teaching practices were administered to characterize perceived growth. While the study did not aim for broad generalization, it prioritized analytic rigor through triangulation across artifacts, observers, and cycles and through member checks during mentor–candidate debriefs.

The analysis proceeded in two layers. First, rubric scores and self-efficacy measures were compared across cycles to detect directional change and to identify dimensions with robust growth versus those that required redesign. Second, thematic analysis of reflections and mentor debriefs sought to explain observed patterns, with particular attention to how candidates reasoned about student evidence, adapted explanations, and used safety and ethics protocols to shape investigations. Iterative adjustments were made after each cycle, such as refining the lesson template to include an explicit space for anticipated alternative conceptions, adding exemplars of feedback comments linked to success criteria, and tightening the observation protocol around teacher talk moves that elicit and press on student explanations.

Across cycles, the methodology yielded consistent improvements in planning quality and in the alignment of instructional components. Early lesson plans often listed broad topics without specifying conceptual goals or the forms of evidence that would demonstrate understanding. By the second and third cycles, plans articulated precise learning objectives tied to disciplinary core ideas and crosscutting concepts, detailed the investigations that would make student reasoning visible, and included concrete plans for collecting and interpreting formative data. Candidates increasingly anticipated well-documented misconceptions, such as conflating respiration with breathing or misinterpreting energy transfer in ecosystems, and designed prompts and models to surface and reshape these ideas rather than bypass them. This change reflects a deepening of pedagogical content knowledge and suggests that structured anticipatory planning can make PCK more actionable in the classroom.

In enactment, mentor observations documented a notable shift from activity-centered lessons to sensemaking-oriented instruction. Rather than treating laboratory tasks as procedural ends, candidates framed investigations as opportunities to test explanations, compare models, and adjudicate claims with data. Discourse patterns gradually moved away from rapid triadic exchanges toward dialogic talk in which students' partial ideas were probed and connected. Candidates became more adept at pressing for warrants and at scaffolding scientific argumentation without turning discussion into teacher-driven recitation. These shifts were most apparent when mentors used a common protocol that named core talk moves and when post-lesson debriefs returned to specific moments in video to analyze choices and alternatives. The presence of a shared language around discourse, developed in methods seminars and reinforced in observations, proved crucial for making tacit professional knowledge discussable.

Formative assessment practices improved in specificity and timeliness. Initially, checks for understanding were generic and loosely tied to objectives, and feedback tended to be evaluative rather than descriptive. Over time, candidates used exit prompts, annotated diagrams, and brief written explanations to collect evidence aligned with the day's learning goals, and their feedback increasingly referenced success criteria and next steps. Student work samples showed clearer opportunities for revision, for instance, by asking learners to reconcile data trends with their initial claims or to refine system models to account for anomalous observations. Candidates learned to use these artifacts to adjust subsequent instruction, not simply to justify grades. The methodological choice to make assessment artifacts central to reflection sessions amplified this growth, as candidates could trace how their prompts elicited certain kinds of reasoning and how different feedback formulations shaped student revisions.

Attention to safety and ethics matured alongside inquiry enactment. Early in the practicum, risk assessments were perfunctory, and ethical considerations about specimen use were often treated as compliance rather than as integral to scientific practice. Through explicit planning prompts and mentor modeling, candidates began to integrate safety briefings as scientific reasoning moments, for example, by having students predict risks associated with respiration probes placed in sealed systems and design mitigations based on gas exchange principles. Ethical discussions expanded beyond consent forms to include considerations of biodiversity impact and humane treatment in fieldwork, thus modeling a broader view of responsible science. These developments indicate that when safety and ethics are positioned as epistemic features of inquiry rather than as add-ons, they contribute to both student learning and teacher readiness.

Reflective judgment showed marked gains as candidates learned to ground their interpretations in evidence from student work and classroom interactions. Early reflections emphasized personal comfort or general impressions; later entries cited specific artifacts, such as a student's evolving model of cellular respiration, and connected instructional decisions to those artifacts. Video-based reflection proved especially powerful because it helped candidates notice missed opportunities to press on ideas, track participation patterns, and examine the timing and content of explanations. The iterative structure of the methodology, with cycles of rehearsal, enactment, and analysis, habituated candidates to treat teaching as design under constraint, where decisions can be improved in light of evidence rather than defended as fixed preferences.

The role of mentoring quality emerged as a decisive contextual factor. Where mentors consistently used the shared observation protocol, modeled disciplinary talk, and pressed candidates to link plans and assessments, growth was accelerated and more evenly distributed across dimensions. In settings where mentoring was sporadic or focused primarily on behavioral management without connecting to disciplinary aims, improvements were narrower and slower. This variation affirms the literature on the importance of programmatic coherence and of mentor preparation for practice-based teacher education. It also justifies investment in mentor calibration sessions and in the provision of concrete tools, such as annotated plan exemplars and discourse move guides, that reduce idiosyncrasy in feedback.

Digital tools contributed positively when their use was explicitly tied to disciplinary practices and formative evidence. For instance, simple data-logging setups in respiration or photosynthesis investigations generated real-time graphs that anchored student argumentation, and video snippets supported precise reflection on questioning and explanation. In contrast, generic presentation software added little when it was not leveraged to scaffold modeling or to visualize complex biological processes. This pattern underlines the utility of technological pedagogical content knowledge as a design lens: technology strengthens readiness when it mediates content-specific pedagogy rather than when it serves as decoration or mere efficiency.

Despite these gains, constraints shaped outcomes. Time pressures in schools limited the number of complete cycles some candidates could experience, and resource inequities affected the feasibility of particular investigations. Where laboratory spaces were constrained or materials were scarce, candidates resorted to demonstrations or simulations, which, while useful, reduced opportunities for students to generate data. Such limitations point to the importance of including low-cost, high-yield tasks in the library of investigations and of building partnerships that pool resources across schools. Another challenge concerned the calibration of mentor feedback; even with a shared protocol, expectations regarding rigor and pacing varied. Addressing this requires continuing mentor learning communities and periodic moderation of artifacts to align interpretations.

Overall, the results support the central claim that school-based practice can substantially enhance the professional and methodological readiness of future biology teachers when it is organized as a deliberate sequence of mentored design, disciplined enactment, and artifact-anchored reflection. The five readiness dimensions appeared mutually reinforcing: improvements in planning enabled more coherent discourse, better formative assessment enabled more targeted explanation, and attention to safety and ethics deepened the authenticity of inquiry. The methodology's design features—a shared planning template keyed to disciplinary practices, a common observation protocol for discourse and evidence use, and a reflective cycle centered on artifacts—were instrumental in translating abstract ideals into practical routines of teaching.

The study advances a replicable methodology for using school-based practice to strengthen the professional and methodological readiness of future biology teachers. By integrating inquiry-centered planning, mentored enactment, and evidence-anchored reflection within iterative cycles, the approach cultivates pedagogical content knowledge, assessment literacy, and reflective judgment while normalizing attention to safety and ethics as integral to scientific practice. The observed growth across cohorts suggests that readiness develops most reliably when programs supply coherent tools, invest in mentor preparation, and make classroom artifacts the core of professional learning. The findings also clarify the conditions under which school-based practice realizes its promise: mentors need a shared language and protocol for observing disciplinary teaching; digital tools should be chosen for their affordances for modeling, data, and feedback; and partnerships must ensure access to investigations that allow students to produce and reason with evidence. Future research should extend this work by examining long-term impacts on graduates' instructional quality and student learning, by testing the methodology in diverse contexts with varying resource constraints, and by exploring how mentor learning communities can sustain calibration over time. For teacher education programs seeking to bridge the theory–practice divide in biology, embedding such structured, reflective, and evidence-seeking school-based practice offers a pragmatic route to meaningful readiness.

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