Assignment Design and Reflections for Bilingual Courses from the Perspective of Hierarchical Cognitive Objectives: A Case Study of the Plant Physiology (Bilingual) Course

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Abstract University-level after-class assignments in bilingual Plant Physiology courses frequently suffer from unclear cognitive objectives, monotonous task structures, and a disconnect between language training and the development of disciplinary thinking. This paper applies the Revised Bloom's Taxonomy of Educational Objectives as a theoretical framework to guide the design of bilingual after-class assignments. It examines the framework's three core advantages: providing a structured pathway for progressing from lower-order to higher-order cognitive tasks, fostering the organic integration of language acquisition with subject-matter thinking, and establishing a foundation for structured diagnostic formative assessment. Using the chapter "Plant Growth Substances" as a case study, the paper presents a suite of six tiered exercises spanning all six cognitive levels-Remember, Understand, Apply, Analyze, Evaluate, and Create. Each exercise is accompanied by flexible language scaffolds calibrated to reduce extraneous cognitive load while maintaining appropriate academic English demands. The proposed framework facilitates a tripartite alignment of instructional objectives, assignment tasks, and assessment evidence, thereby transforming after-class assignments into effective instruments for formative assessment. This approach offers practical implications for cultivating students' professional competency, higher-order thinking skills, and academic English proficiency within bilingual disciplinary courses.

Key words Revised Bloom's Taxonomy, Bilingual instruction, After-class assignment design, Plant physiology, Higher-order thinking

0 Introduction

Plant physiology constitutes a core foundational course for students in agriculture, forestry, and biology-related programs. It plays a crucial role in shaping students' comprehension of subsequent cultivation-related subjects and in building their capacity for scientific research[1-3]. A substantial proportion of frontier research in this field is published in English, making bilingual instruction a valuable tool for enhancing students' professional English reading comprehension, expression, and academic communication skills[4-5]. However, the implementation of bilingual teaching at the university level often encounters significant challenges. Students may possess a relatively weak English foundation, while the subject matter of plant physiology itself involves abstract mechanisms and an extensive conceptual framework. Compounding this, after-class assignments frequently remain anchored at the levels of rote memorization and simple comprehension. These assignments often suffer from ambiguous objectives, a monotonous task structure, and inconsistent evaluation criteria, which collectively hinder their effectiveness in promoting genuine knowledge transfer and the development of higher-order cognitive skills.

The Revised Bloom's Taxonomy of Educational Objectives offers an operable, two-dimensional framework based on the "cognitive process" and "knowledge" dimensions. This taxonomy provides a mechanism for refining assignment objectives into progressive hierarchical levels and for naturally embedding language practice within subject-matter thinking tasks[6-8]. Grounded in this theoretical perspective, the present paper focuses on the design of after-class assignments for the university-level Plant Physiology (Bilingual) course. It explores how this taxonomy can be utilized to achieve alignment among assignment objectives, task design, and evaluation evidence. Through concrete examples of tiered exercises, the paper demonstrates a practical approach to enhancing the formative assessment efficacy of assignments and to promoting the synergistic development of students' mastery of professional knowledge and their proficiency in academic English.

1 Application of the Revised Bloom's Taxonomy of Educational Objectives in bilingual after-class assignment design

1.1 Practical challenges in bilingual after-class assignment design

After-class assignments serve as a critical extension and supplement to classroom instruction. They function as a primary mechanism for students to consolidate knowledge, internalize concepts, and develop competencies, while simultaneously providing a key channel for instructors to gather learning feedback and adjust pedagogical strategies. Nevertheless, within the current practice of bilingual plant physiology instruction in higher education, the design of after-class assignments frequently lacks a systematic framework grounded in hierarchical cognitive objectives. Assignments are predominantly composed of question types—such as term definitions, fill-in-the-blank exercises, and short-answer questions—

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that primarily assess memory and basic comprehension. There is often limited engagement with higher-order thinking processes such as analysis, evaluation, and creation. Concurrently, while bilingual instruction imposes additional demands on students' professional English proficiency, existing assignment designs seldom achieve a deep integration of language training with disciplinary thinking development. This disconnect can readily lead to a parallel, rather than integrated, cultivation of language competency and professional quality[5]. Consequently, introducing a scientific and systematic taxonomy of educational objectives to guide the design of after-class assignments is of significant importance for improving the overall quality and effectiveness of bilingual instruction.

1.2 Basic framework of the revised bloom's taxonomy *The Revised Bloom's Taxonomy of Educational Objectives* organizes the cognitive process dimension into six hierarchically ordered levels: Remember, Understand, Apply, Analyze, Evaluate, and Create[7]. A key revision from the original taxonomy is the replacement of "Synthesis" with "Create," which is positioned at the highest level of cognitive complexity. Furthermore, the revised taxonomy introduces a complementary knowledge dimension, comprising factual, conceptual, procedural, and metacognitive knowledge. This creates a two-dimensional matrix (cognitive process × knowledge type), which provides educators with a more refined and powerful analytical tool for the precise articulation of instructional objectives and the systematic, structured design of learning tasks and assessments[8].

1.3 Key advantages of the Revised Bloom's Taxonomy for guiding bilingual assignment design The Revised Bloom's Taxonomy offers a structured and progressive pathway for designing bilingual assignments, facilitating the systematic development of cognitive skills from foundational to advanced levels. For instance, at the Rememberlevel, exercises such as matching hormone names with their functions help establish core disciplinary vocabulary. The Understandlevel requires students to explain mechanisms in their own words, demonstrating comprehension. Applytasks challenge students to transfer knowledge to novel scenarios, such as explaining an agricultural application. Analyzeexercises demand the comparison and contrast of hormonal interactions or the interpretation of graphical data. Evaluatetasks involve constructing evidence-based arguments regarding scientific claims, while Create—the highest level—challenges students to synthesize knowledge to design an original experiment or protocol. This tiered approach ensures intentional alignment between instructional goals ("what to teach"), practice tasks ("how to practice"), and assessment evidence ("how to know they learned"), moving assignment design beyond subjective or ad-hoc practices[9].

A further advantage is the framework's capacity to organically integrate language training with subject-matter thinking. Lower-order tasks can focus on vocabulary accuracy and simple sentence structures (*e.g.*, defining terms in English). As tasks ascend the cognitive hierarchy, they inherently require more sophisticated use of academic English for complex reasoning—such as constructing coherent arguments at the Analyzeor Evaluatelevels, or presenting a detailed methodology at the Createlevel. To manage the dual cognitive load of processing complex content in a second language, the design incorporates flexible linguistic scaffolds. These may include permitting Chinese – English mixed expression for complex reasoning tasks or providing glossaries of key terminology. Such scaffolds help reduce extraneous cognitive load[10-11], directing students' primary cognitive resources toward engaging with the disciplinary content rather than being overwhelmed by language production barriers.

Critically, this structured framework transforms assignments from mere homework into powerful formative assessment tools. By explicitly mapping student responses to specific cognitive levels, instructors can diagnostically pinpoint learning gaps—for example, identifying a cohort that excels at Rememberand Understandbut struggles with Apply. This enables the provision of targeted, level-specific feedback and the adjustment of instructional strategies. This process embodies the formative assessment principle of "promoting learning through assessment," as evidence of mastery (or lack thereof) across the six levels is directly linked to actionable teaching interventions[12-13]. The ultimate outcome is the synergistic growth of students' professional knowledge, higher-order thinking skills, and academic English proficiency.

In summary, the Revised Bloom's Taxonomy provides a systematic, theory-informed framework for designing bilingual after-class assignments in plant physiology. It offers guidance across three critical dimensions: establishing hierarchical cognitive objectives, integrating language and content learning, and enabling diagnostic formative assessment. The following section will use the chapter "Plant Growth Substances" as a detailed case study to concretely demonstrate the design approach for a set of six-level after-class exercises based on this framework.

2 Sample after-class exercise design based on the Revised Bloom's Taxonomy: a case study of "Plant Growth Substances"

The chapter "Plant Growth Substances" is a core component of the Plant Physiology curriculum. It encompasses the chemical properties, biosynthesis, signal transduction, and physiological functions of the five major classes of plant hormones—Auxin, Gibberellin, Cytokinin, Abscisic Acid (ABA), and Ethylene—as well as the complex interactions and regulatory networks among them[2]. This chapter features a rich conceptual framework with clearly delineated knowledge levels: it includes a substantial body of foundational terminology and factual knowledge requiring memorization, while also presenting numerous scientific questions amenable to analysis, evaluation, and creative exploration. It is therefore exceptionally well-suited for illustrating the design of multi-level after-class exercises guided by Bloom's Taxonomy. Presented below are corresponding exercises for the six cognitive levels. Each exercise is annotated with its target cognitive level and design rationale, and incorporates flexible language requirements to accommodate the diverse learning needs and English proficiencies within a typical bilingual classroom.

2.1 Level 1: Remember

2.1.1 Exercise 1. Please match the English names of plant hormones listed in the left column with their primary functional descriptions in the right column (Table 1).

Table 1 Matching exercise on plant hormone names and functions

Plant hormone	Functional description
A. Auxin	① Promotes seed dormancy and stomatal closure
B. Gibberellin	② Stimulates fruit ripening and leaf senescence
C. Cytokinin	③ Promotes cell elongation and apical dominance
D. Abscisic Acid (ABA)	④ Promotes stem elongation and seed germination
E. Ethylene	⑤ Promotes cell division and delays senescence

2.1.2 Design rationale. This exercise corresponds to the Rememberlevel, the foundational tier of cognition. It is designed to assess students' basic recognition and recall of the English nomenclature and core physiological functions of the five major plant hormone classes. The matching format provides a low-threshold activity that helps students establish and reinforce essential connections between key professional vocabulary and fundamental subject-matter knowledge.

2.2 Level 2: Understand

2.2.1 Exercise 2. Polar auxin transport is a critical mechanism underlying many of auxin's physiological functions. Using relevant English terminology, please explain in your own words: (a) what polar auxin transport is, and (b) describe its key physiological significance for plant growth and development.

2.2.2 Design rationale. This exercise targets the Understandlevel. It requires students to move beyond simple recall, demanding that they comprehend the concept of "polar auxin transport" sufficiently to explain and articulate its significance in their own language. This assesses genuine conceptual understanding rather than verbatim repetition. The requirement to incorporate relevant English terminology simultaneously trains students' ability to accurately employ professional vocabulary within explanatory contexts.

2.3 Level 3: Apply

2.3.1 Exercise 3. In agricultural production, fruit growers commonly use ethephon (a chemical agent that releases ethylene) to promote and synchronize fruit ripening. Suppose you are an agricultural technician who needs to advise a group of fruit growers. Please prepare a brief explanation that covers: (a) the scientific reason why ethephon accelerates fruit ripening, and (b) key precautions that should be observed during its application to ensure effectiveness and safety. Present your recommendations in English, or using a combination of Chinese and English as needed.

2.3.2 Design rationale. This exercise corresponds to the Apply level. It requires students to transfer and apply their theoretical knowledge of ethylene's role in fruit ripening to a specific, real-world agricultural context. This assesses the capacity for knowledge application beyond the textbook. The flexible language requirement ("Chinese – English mixed expression") is intentional, designed to reduce the extraneous cognitive load associated with producing flawless academic English. This allows students to concentrate their primary cognitive effort on the core task of applying subject-matter knowledge to solve a practical problem.

2.4 Level 4: Analyze

2.4.1 Exercise 4. The figure below (assumed to be provided) presents dose-response curves illustrating the effects of different concentrations of Auxin (IAA) on the elongation growth of roots, buds, and stems. Based on your analysis of the graph, please answer the following questions:

(a) How do the optimal IAA concentrations for promoting growth differ among roots, buds, and stems?

(b) What general trend is observed in the growth response of each organ when the IAA concentration exceeds its optimal level?

(c) What fundamental characteristic of auxin's physiological action is illustrated by these differential responses?

Please use relevant English terminology in your analysis.

2.4.2 Design rationale. This exercise aligns with the Analyze level. It requires students to break down the provided graphical data, identify and compare patterns (differences in sensitivity among organs), distinguish between promoting and inhibiting effects, and infer the underlying biological principle—namely, the dual effects of auxin and the differential sensitivity of plant tissues. This assesses students' ability to deconstruct information, differentiate relationships, and synthesize specific data into generalizable scientific concepts.

2.5 Level 5: Evaluate

2.5.1 Exercise 5. In early plant physiology research, Abscisic Acid (ABA) was predominantly characterized as a "growth inhibitor" due to its observed effects in promoting leaf abscission and inhibiting growth. However, contemporary research has revealed significant positive regulatory roles for ABA in processes such as seed development, osmotic stress tolerance, and stomatal regulation. Critically evaluate the historical viewpoint that "ABA is merely a growth inhibitor." Your evaluation should address:

(a) What experimental evidence originally supported this viewpoint?

(b) What subsequent experimental evidence challenges or refutes this simplistic view?

(c) Based on the synthesis of this evidence, how should the physiological functions of ABA be understood in a more comprehensive and nuanced manner?

Present your reasoned argument in English, or a combination of Chinese and English.

2.5.2 Design rationale. This task corresponds to the Evaluatelevel, a high-order cognitive skill. It requires students to gather, appraise, and synthesize evidence from both supporting and opposing perspectives on a scientific claim. They must then make and justify a well-reasoned, comprehensive judgment. This not only assesses deep understanding of ABA's multifaceted roles but, more importantly, trains critical thinking: the ability to construct scientific arguments based on evidence, weigh conflicting positions, and arrive at balanced, evidence-based conclusions. Organizing this complex argument in English simultaneously challenges and enhances students' capacity for logical academic expression in the target language.

2.6 Level 6: Create

2.6.1 Exercise 6. It is established that the phytohormone ethylene plays a significant role in promoting leaf senescence. Design a simple but methodologically sound experimental protocol to test the following hypothesis: "Exogenous application of ethylene accelerates the senescence process in detached leaves."

Your protocol should include:

(a) Experimental materials and a detailed treatment group design (including an appropriate control group).

(b) Detection indicators: Propose at least two quantifiable, senescence-related physiological or biochemical indicators that you would measure.

(c) Expected results: Describe the expected outcomes for your treatment vs. control groups if the hypothesis is correct.

Please write your experimental protocol in English, or a combination of Chinese and English to ensure clarity of the experimental logic.

2.6.2 Design rationale. This exercise targets the Createlevel, the pinnacle of Bloom's Taxonomy. It requires students to synthesize existing knowledge of ethylene and senescence to independently generate a novel, complete experimental design. Students must operationalize a theoretical hypothesis into a practical, logically coherent protocol. This complex process involves defining variables, constructing experimental logic, implementing controls, and selecting appropriate measurement indicators, thereby comprehensively training core competencies in scientific inquiry and experimental design. Formulating the protocol in English adds a significant layer of challenge to academic language organization. Given the high intrinsic cognitive load of the design task itself, the permission for Chinese – English mixed expression serves as a crucial scaffold to reduce extraneous language-related load[11]. This ensures students can dedicate their primary cognitive resources to the creative and analytical demands of experimental design.

2.7 Summary The six exercises presented above are sequentially structured across the six cognitive levels of the Revised Bloom's Taxonomy, forming a coherent progression from foundational knowledge recall to creative synthesis. The exercises are internally connected: the vocabulary and conceptual understanding solidified at lower levels (Remember, Understand) provide the necessary scaffold for the analysis, evaluation, and creation required at higher levels. Concurrently, the cognitive demands exhibit a deliberate gradient, progressively guiding students from surface-level learning to deep learning through recognition, explanation, application, analytical reasoning, critical judgment, and solution design. Regarding language, each exercise incorporates calibrated linguistic scaffolds. Lower-order tasks emphasize accurate use of discrete terminology, while higher-order tasks require more extended academic English discourse but permit strategic code-mixing. This balanced approach seeks to maintain the depth of disciplinary thinking while managing the accessibility of language production. Overall, this hierarchical design ensures each exercise serves a specific cognitive objective while providing instructors with structured evidence to diagnose student mastery across different levels of understanding.

3 Discussion and prospects

3.1 Discussion Focusing on the critical instructional element of after-class assignments within the context of university-level bilingual plant physiology teaching, this paper has systematically explored the application of the Revised Bloom's Taxonomy of Educational Objectives. The discussion has centered on its utility for formulating precise assignment objectives, designing hierarchically structured tasks, and implementing formative assessment. The theoretical analysis has elucidated the framework's advantages, and the case study of the "Plant Growth Substances" chapter has provided a concrete demonstration of a six-level exercise design. Collectively, the analysis indicates that Bloom's Taxonomy can offer a structurally clear and practically operable framework for bilingual assignment design in plant physiology, contributing to a systematic enhancement in the cognitive rigor, intentionality, and instructional feedback value of assignments.

3.1.1 The formative assessment function of hierarchically designed assignments. From an instructional design perspective, the six cognitive levels of Bloom's Taxonomy provide instructors with a principled pathway for designing assignments that scaffold thinking from lower-order to higher-order processes. This approach helps ensure that the goal-setting for after-class assignments moves beyond reliance on personal experience or subjective judgment. Instead, it is guided by an explicit cognitive hierarchy, facilitating the crucial tripartite alignment of instructional objectives, assignment tasks, and assessment evidence[9]. The core value of this alignment is that it allows instructors to precisely determine "what level of mastery is expected" and "what tasks will validly elicit evidence of that mastery." This ensures every exercise serves a deliberate instructional purpose, mitigating arbitrariness and low-level repetition in assignment design.

In bilingual contexts, hierarchical design enables the organic fusion of language training and disciplinary thinking. As exemplified in Section 2, lower-order assignments (*e. g.*, matching terms) help students build an essential professional vocabulary base. In contrast, higher-order assignments (*e. g.*, evaluating a scientific claim or designing an experiment) require students to engage in complex subject-matter reasoning—analysis, evaluation, creation—while simultaneously navigating the linguistic demands of articulating that reasoning in (academic) English. This integration helps avoid the "two-track" problem where language and content learning proceed in parallel without meaningful intersection.

Furthermore, hierarchically designed assignments provide a structured foundation for formative assessment. The essence of formative assessment lies in collecting evidence of learning duringthe instructional process to inform adjustments in teaching and learning[12]. Hierarchical assignments allow instructors to diagnostically pinpoint at which cognitive leveldifficulties arise—be it in foundational knowledge recall, comprehension, application, or higher-order analysis. Research underscores that feedback is among the most potent influences on learning, but its efficacy depends critically on its specificity and timing[13]. The level-specific diagnosis afforded by Bloom's Taxonomy creates the conditions for providing precisely targeted and actionable feedback. Consequently, after-class assignments can be transformed from tools primarily for summative scoring into powerful instruments for formative assessment that actively "promote learning".

3.1.2 Managing cognitive load in bilingual contexts. A critical consideration when applying Bloom's Taxonomy to bilingual assignment design is the judicious management of cognitive load. Cognitive Load Theory posits that instructional design must account for the severe limitations of working memory capacity[11]. In bilingual settings, students intrinsically face a high load as they must simultaneously process complex subject content and foreign language information. Therefore, when designing high-cognitive-load tasks (*e. g.*, creating an experimental protocol in English), it is essential to provide appropriate linguistic scaffolds. The strategies exemplified in our design—permitting Chinese – English mixed expression for complex reasoning and providing key terminology—are deliberate measures to reduce extraneouscognitive load. This helps ensure that students' finite cognitive resources are focused on the essential germaneload of the disciplinary thinking activity itself. Future research could fruitfully draw on Cognitive Load Theory to systematically investigate the interaction effects between language demand and cognitive task level in bilingual assignments, providing empirical data to optimize the difficulty gradient of such tasks.

3.1.3 Limitations. It is important to acknowledge that the discussion in this paper is primarily based on theoretical exposition and illustrative case analysis. The proposed hierarchical assignment design framework has not yet been subjected to systematic, empirical validation within actual teaching practice. Several important questions remain for future investigation: To what extent do hierarchically designed assignments empirically improve students' performance in higher-order thinking and their professional English proficiency? What is the optimal configuration or ratio of assignments across the different cognitive levels? How do students' acceptance, engagement, and intrinsic motivation respond to such structured assignments? Robust empirical studies are needed to answer these questions and refine the approach.

3.2 Prospects Future research should pursue several promising directions. First, quasi-experimental studies comparing learning outcomes from Bloom's Taxonomy-based assignments with those from traditional models are needed. Such research could quantify the impact on higher-order thinking skills, discipline-specific English proficiency, and student motivation. Second, the potential of generative artificial intelligence (AI) in this domain warrants exploration. AI could assist in generating tiered exercise prompts, providing instant, preliminary feedback on language and content, and enabling analytics-driven diagnosis of class-wide cognitive bottlenecks. The key challenge will be to ensure AI supports, rather than replaces, pedagogical judgment and the human feedback loop[14]. Third, the model requires validation across diverse contexts—different course chapters, institutional settings, and student populations with varying English proficiencies. This will help develop differentiated strategies and best practices. Finally, practical implementation could be scaled through the development of digital resource repositories. These could integrate assignment templates, grading rubrics aligned to cognitive levels, and learning analytics dashboards within common teaching platforms, thereby lowering the adoption barrier for instructors and facilitating wider dissemination of the approach.

3.3 Conclusion In conclusion, applying the Revised Bloom's Taxonomy of Educational Objectives to the design of after-class assignments in bilingual plant physiology instruction offers a coherent and practical framework for achieving close integration among instructional objectives, learning tasks, and assessment. This design approach not only assists students in progressively consolidating their professional knowledge and enhancing their academic English proficiency through a structured cognitive journey but also provides instructors with a systematic tool for conducting diagnostic formative assessment and engaging in continuous instructional improvement. It holds significant positive implications for cultivating a new generation of agricultural and forestry professionals who possess solid disciplinary expertise, the ability for international academic communication, and well-developed innovative thinking capacities.

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