

Development of an Experimental Curriculum Design Case for Enhancing Middle School Students' Scientific Inquiry Literacy Under China's "Double Reduction" Policy: A Case Study of "Investigating Differences in Catalase Content Among Different Plant Organs"

Sun Yangjie¹, Li Wenling², Liu Bin³

¹ School of Agriculture and Biology, Guangxi Minzu Normal University, Chongzuo 532200, Guangxi, China

² School of Education Science, Guangxi Minzu Normal University, Chongzuo 532200, Guangxi, China

³ School of Liberal Arts and Mass Media, Guangxi Minzu Normal University, Chongzuo 532200, Guangxi, China

ABSTRACT: The continued implementation of China's "Double Reduction" policy has placed higher expectations on middle school students' autonomous learning ability and experimental inquiry literacy. To promote students' disciplinary core competencies, routine classroom teaching must be comprehensively reformed. Traditional, rigid teaching models and classroom formats are no longer sufficient to meet the diversified educational needs arising under the "Double Reduction" context. Therefore, the active development of inquiry-based experiments and scientifically designed experimental courses that encourage students to conduct autonomous exploration during their spare time has become an important practical pathway for current curriculum reform. Such curriculum design not only aligns with the specific requirements of curriculum standards, but also connects school-based curricula with after-school, weekend, and holiday learning time. Compared with conventional teaching models, it can reduce students' course-related pressure while effectively improving their comprehensive scientific inquiry literacy.

KEYWORDS: curriculum reform; "Double Reduction" policy; inquiry experiment; case development

The implementation of the "Double Reduction" policy aims to reduce students' learning burden, improve classroom efficiency, provide students with more extracurricular time, and enhance their self-directed learning and autonomous inquiry abilities, thereby implementing the educational principle of fostering virtue through education. In curriculum teaching, competency-oriented challenging problems should be created to guide students in analysing and solving problems and to improve their learning interest and scientific literacy (Wang, 2025). In biology teaching, teachers must transform their educational concepts, enrich classroom teaching methods, create new forms of classroom instruction, and guide students to make full use of modern network technologies so as to integrate practical experimental teaching with life-oriented learning (Xie, 2023). By offering innovative inquiry-based experimental courses, learning can be extended from the classroom to everyday life, enabling students to shift from passive knowledge reception to active exploration and research. This process not only improves educational quality but also cultivates students' scientific inquiry literacy.

1. Transformation of Disciplinary Teaching Concepts under the "Double Reduction" Policy

In 2021, China formally implemented the "Double Reduction" policy, which has had a profound influence on basic education. On the one hand, the policy has effectively reduced students' excessive academic workload. Within school teaching systems, the proportion of traditional instruction dominated by mechanical memorisation and repetitive test drilling has decreased significantly. The provision of school-based, practical, and distinctive courses has offered students more time for autonomous learning and practical exploration. On the other hand, by regulating the operation and management of off-campus tutoring institutions, the policy has alleviated the unreasonable occupation of students' weekends and holidays by various tutoring programmes, thereby making students' extracurricular time more sufficient.

Under the background of the "Double Reduction" policy, high school biology teaching should strictly follow the principle of teaching students in accordance with their aptitude. It should organically integrate the systematic teaching of theoretical knowledge with in-depth practical teaching, actively adopt group cooperative learning, and promote the construction of new experimental classrooms from multiple dimensions, including teaching objectives, teaching methods, and evaluation systems, so as to comprehensively improve students' classroom learning efficiency and learning quality (Li, 2024). In addition, high-quality practical

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assignments can enable students to explore the essence of knowledge through practical experience, deepen their understanding of knowledge through practice, improve their ability to transfer knowledge, and cultivate their hands-on operational ability (Wan, 2024). Therefore, in order to develop quality-oriented education, it is of important practical significance and feasibility to develop experimental courses that integrate school-based curricula with after-school life, align closely with new college entrance examination question types, and effectively enhance students' inquiry-based learning thinking.

2. Principles for Designing Inquiry-Based Experiments for Middle School Students

2.1 Positioning Experimental Content Based on Curriculum Standards and Textbook Content

The section on enzymes is the first formal inquiry-based experimental content encountered by middle school students since they began systematic biology learning. It serves as a key transitional link in the complete knowledge system of high school biology. It not only effectively connects previously learned theoretical knowledge such as cellular metabolism and substance transport, but also lays a solid methodological and cognitive foundation for subsequent inquiry and analysis of core physiological processes such as photosynthesis and respiration.

When explaining the core properties of enzymes, this section specifically includes three classic inquiry experiments: "enzymes have high catalytic efficiency", "enzymes are substrate-specific", and "enzyme activity requires relatively mild conditions". Meanwhile, the chapter systematically addresses factors affecting enzyme-catalysed reaction rates, among which the effect of enzyme concentration on reaction rate is one of the core knowledge points.

2.2 Principles of Experimental Design

During the normal growth and development of animals and plants, hydrogen peroxide is continuously produced as a metabolic product within cells. This substance has strong oxidising properties and can seriously damage cellular structures and functions. Under special adverse environmental conditions such as drought, saline-alkali soil, and extreme temperatures, plant cells produce more reactive oxygen species, thereby generating oxidative stress and causing more severe cellular damage (Nan & Fan, 2008). Because different plant organs differ significantly in physiological function and growth environment, the amount of hydrogen peroxide produced in their cells also differs markedly, and corresponding differences in catalase content may also occur.

Considering the limitations of hardware facilities and operating conditions in middle school experimental courses, it is difficult to directly determine the exact content of catalase. Moreover, the core objective of this experiment is only to compare relative differences in catalase content among different plant organs, rather than to perform precise quantitative analysis. Therefore, the indirect measurement approach used in the photosynthesis chapter of high school biology—in which carbon dioxide absorption is used to represent net photosynthetic rate—can be adopted. Specifically, by measuring the volume of oxygen generated from the decomposition of hydrogen peroxide under enzymatic catalysis, the decomposition rate of hydrogen peroxide can be calculated, thereby indirectly reflecting the relative catalase content of different plant organs.

Based on the above scientific principles, and in combination with the design logic of inquiry experiments and the operational norms of classic textbook experiments in Compulsory Biology 1, an inquiry-based experiment entitled "Investigating differences in catalase content among plant roots, stems, leaves, flowers, and fruits" is designed. This experiment integrates theoretical knowledge with experimental practice and helps students master the basic design methods, operational procedures, and analytical approaches of inquiry-based experiments.

2.3 Principles for Selecting Experimental Materials

The design of this experiment should strictly follow the basic principles of safety first, simple operation, and controllable cost. Given differences in experimental funding among regions and schools, the selection of experimental apparatus should prioritise items that are readily available in daily life, routinely equipped in middle school laboratories, and easy to operate, such as small beakers, mortars, glass rods, funnels, and other basic apparatus. For data measurement, a household needle-free graduated syringe may be used for rough measurement. This approach reduces operational difficulty while controlling experimental cost. In terms of reagents, a commonly used and relatively safe 3% hydrogen peroxide solution should be selected, and toxic, harmful, or highly corrosive reagents should be avoided.

The selection of test samples should meet the core requirements of structural integrity, freshness, absence of spoilage, and non-toxicity. It is recommended that complete and healthy plants with roots, stems, and leaves, such as spinach and coriander, be purchased from regular markets. This can effectively avoid potential health risks to students caused by toxic or harmful substances in unfamiliar plants, while also ensuring the uniformity and reliability of experimental materials.

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3. Experimental Design and Practical Implementation Plan

3.1 Experimental Design and Practical Process

With appropriate guidance and inspiration from the teacher, students may independently design the experimental plan by referring to the classic design ideas of inquiry experiments in the enzyme section. During the preparation of experimental materials, the extraction process for catalase can be optimised by drawing on the extraction method for photosynthetic pigments in the photosynthesis chapter. For example, target organs such as roots, stems, and leaves may be cut from complete and healthy plants purchased from a regular market. After the organs are rinsed with clean water and the surface moisture is wiped dry, equal masses of tissues from each organ are accurately selected, cut into small pieces with scissors, and ground in a mortar. Before grinding, a small amount of silicon dioxide and calcium carbonate should be added to the mortar. Silicon dioxide ensures sufficient grinding, while calcium carbonate effectively maintains the acid-base balance of the grinding system and protects the biological activity of catalase from damage. After grinding, the homogenate is filtered with clean nylon cloth or gauze, and the filtrate is carefully collected in a clean beaker for later use. At the same time, another beaker of the same specification is prepared, and approximately 0.10 g of catalase powder with an activity of 100,000 U/g is accurately added as the experimental control group to verify the validity of the experimental system. Because the water content of different plant tissues varies naturally, distilled water should be added to the beakers containing each filtrate until the liquid levels are the same. This ensures that the solvent mass in each experimental group is basically consistent while avoiding excessive dilution of catalase, which could result in an overly low enzymatic decomposition rate and unclear experimental phenomena.

After the experimental materials are prepared, the formal experimental procedure can begin. Taking a class of 45 students as an example, group cooperation may be adopted with at least five students in each group. Each group independently selects one plant as the experimental object, and members within the group should have clear task assignments. For example, one student may be responsible for accurate timing, while the other members are respectively responsible for the experimental operation of one plant-organ extract or the control enzyme solution, thereby ensuring an orderly experimental process.

In the specific experimental operation, the teacher may provide standardised reference guidance. For instance, students first draw a certain amount of 3% hydrogen peroxide solution into a syringe, slowly expel the residual air from the barrel, and then accurately draw hydrogen peroxide solution again to the 2 mL mark, ensuring that all group members use exactly the same volume of hydrogen peroxide solution. Subsequently, under the instruction of the student responsible for timing, all members simultaneously draw the corresponding concentration of extract or control enzyme solution into the syringe, quickly mix it by shaking, start the timer synchronously, and record experimental data at the predetermined time points.

During the experimental design process, the teacher provides only procedural and principled reference suggestions. Each group is encouraged to use the time reserved before or during class for several minutes of focused discussion, independently optimise the design, and determine the final experimental plan. If some groups propose different experimental designs or innovative improvements based on experimental principles or operational practice, the teacher may organise a whole-class discussion and feasibility analysis. In this way, students' independent thinking and innovative thinking can be fully cultivated, and their scientific inquiry literacy can be further enhanced.

3.2 Data Analysis

During the experiment, students should synchronously record data strictly according to the predetermined time points to ensure the authenticity and completeness of the data. The teacher may set appropriate data-recording time points based on long-term teaching experience and the scientific requirements of the experiment. For example, five time points—2 min, 4 min, 6 min, 8 min, and 10 min—may be set to record the volume of oxygen generated in the syringe at each time point. The average oxygen production rate can then be calculated based on the change in volume and the time interval. To reduce random errors, each group should conduct three parallel measurements, and the average of the three measurements should be taken as the final valid data. The data are recorded in the experimental observation record sheet (Table 1). On this basis, each group should further plot the trend curve of oxygen production over time in the oxygen production comparison chart (Figure 1), and plot the calculated comparison curve of oxygen production rate in the chart showing the catalytic decomposition rate of hydrogen peroxide by extracts from different plant organs (Figure 2). Students should then carry out targeted data analysis and discussion based on the characteristics of the curves.

The teacher should distribute uniform experimental recording charts to each group in advance. After each group member records the data for the experiment they are responsible for, the group leader summarises and organises the data, integrating the oxygen production volume and production rate corresponding to different plant organs into the same charts. This provides clear and intuitive data support for subsequent intra-group analysis and inter-group communication.

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Table 1. Experimental Observation Record Sheet

Plant organ: _____ Oxygen production (mL)					
Time (min)	First measurement	Second measurement	Third measurement	Mean	Control group
2					
4					
6					
8					
10					
Average rate (mL/min):					

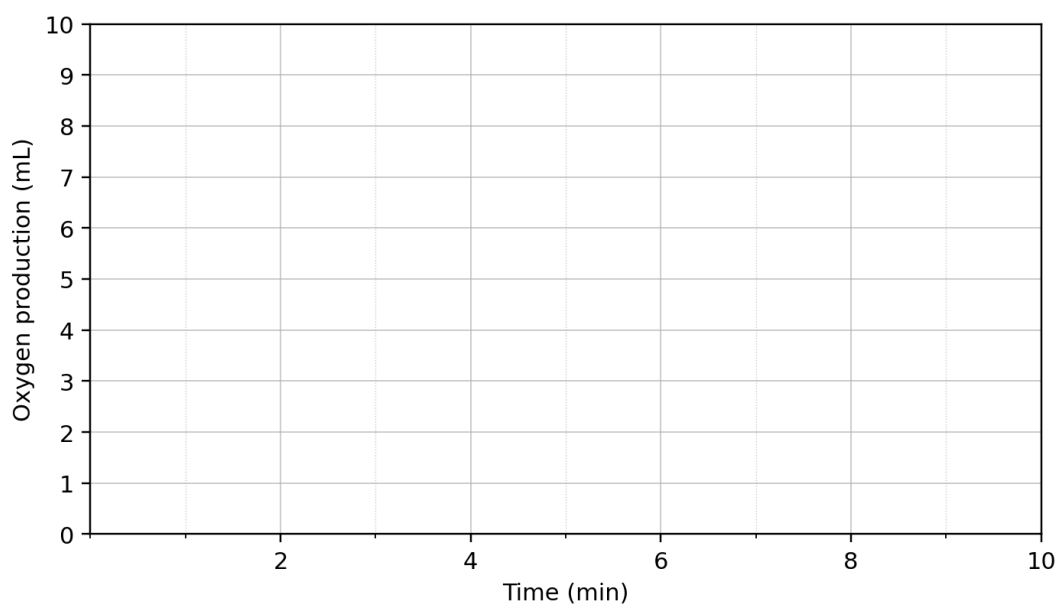


Figure 1. Comparison chart of oxygen production over time. Students plot oxygen production (mL) against time (min) for different plant organs and the control group.

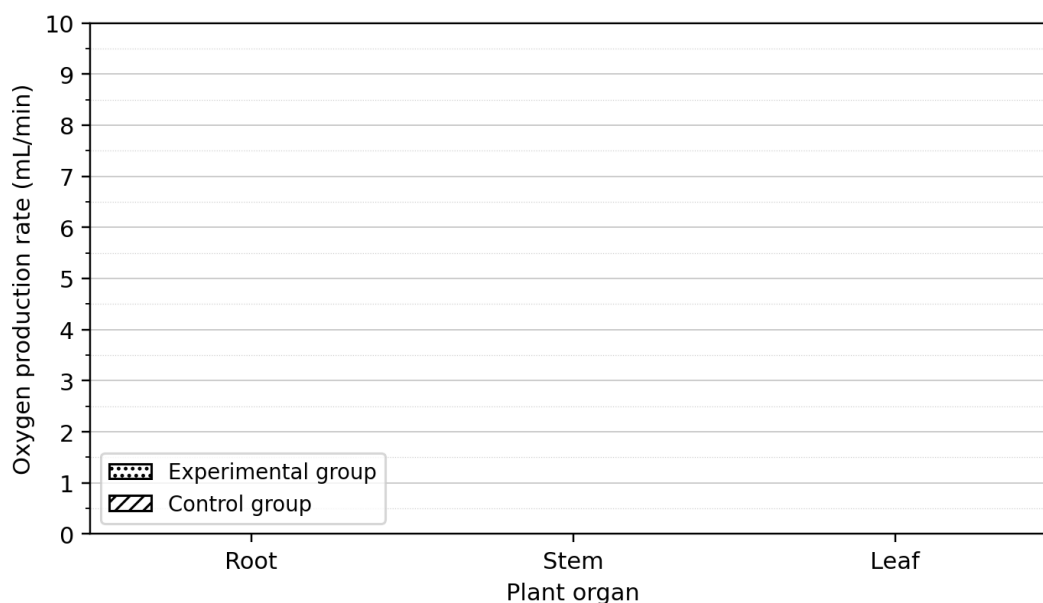


Figure 2. Comparison chart of hydrogen peroxide decomposition rates catalysed by extracts from different plant organs. Students compare the calculated oxygen production rates for roots, stems, leaves, and other sampled organs.

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3.3 Discussion and Summary of Experimental Results

The core teaching objective of this experiment is to cultivate students' autonomous inquiry ability and scientific thinking ability. Therefore, the experimental conclusions should be drawn independently by students through autonomous discussion, logical reasoning, and in-depth thinking. The teacher may pre-design several guiding questions but should minimise direct intervention in the process of conclusion formation. The specific process is as follows. After each group completes the recording, checking, and organisation of all experimental data, members first conduct a brief but in-depth group discussion. Based on the experimental data, students initially draw conclusions, for example, identifying which plant organs show relatively high catalase content and which show relatively low content. They then analyse possible reasons for the differences in enzyme content among different organs by combining experimental principles with data characteristics, attempt to explain the experimental phenomena, and form preliminary experimental conclusions.

Next, each group selects a representative to share with the whole class the group's experimental process, data results, and preliminary conclusions. Group representatives engage in cross-discussion around issues such as data differences and the reasonableness of conclusions, thereby forming a stage-based consensus. Finally, the consensus conclusions are presented to the whole class, and all students are organised to think, supplement, and refine them together, ultimately reaching scientific and rigorous experimental conclusions. At the end of the course, students may be asked to reflect actively on the shortcomings of this experiment, the problems they encountered during the experimental process, and possible improvement methods based on the inquiry-based experimental content and procedures learned from the textbook. This helps improve students' practical experimental ability.

3.4 Experimental Extension

After the experimental operation is completed, the teacher may design targeted after-class assignments to complete the closed-loop system of experimental teaching. For example, two experimental inquiry questions closely related to the experimental content and based on material analysis and data processing may be carefully assigned. These questions can help students consolidate the knowledge and methods learned through the experiment, while also enabling the teacher to obtain timely teaching feedback, accurately understand the improvement of students' experimental inquiry ability, and provide a scientific basis for subsequent lesson preparation optimisation and teaching adjustment. In addition, students should be required to properly retain the original data and final results of the experiment. During weekend spare time, they can use mainstream AIGC tools, consult academic literature, seek advice from biology professionals, and adopt other diversified approaches to verify the scientific validity and reliability of the experimental results. Through autonomous inquiry, students can find solid theoretical support for their experimental conclusions.

In the process of result verification and further inquiry, the teacher may guide students through online question-answering, offline tutoring, and other methods to actively explore the internal physiological mechanisms and environmental adaptive significance of differences in catalase content among plant organs. The inquiry may be further extended to practical issues such as plant stress-resistance breeding and ecological environmental protection, thereby further implementing the core competencies of biology, including life concepts, scientific thinking, scientific inquiry, and social responsibility.

4. CONCLUSION

In summary, the continued reform of new college entrance examination question types has imposed more rigorous requirements on students' data analysis ability, experimental design ability, and inquiry thinking ability. Traditional classroom teaching has long been oriented toward the systematic transmission of theoretical knowledge. Constrained by heavy teaching pressure and relatively tight lesson schedules, it is difficult for such teaching to effectively improve students' practical experimental ability and innovative thinking ability. The comprehensive implementation of the "Double Reduction" policy has provided students with more sufficient time for autonomous learning and practical exploration by reducing their excessive academic burden. Although schools have appropriately reduced the total amount of theoretical teaching content and substantially alleviated students' academic workload, they must increase investment in the construction of innovative experimental courses in response to the higher requirements of the new college entrance examination for students' experimental inquiry ability and its more flexible question types. Making full use of students' extracurricular time and school-based curriculum resources, systematically developing innovative experimental projects, driving students to conduct autonomous inquiry-based learning, and combining new teaching models with group cooperative learning have become important directions for high school biology teaching reform under the background of the new curriculum reform. These measures can comprehensively improve students' experimental analysis ability, innovative practical ability, and cooperative learning ability.

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