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Designing an Interdisciplinary Project-Based Learning Unit of TCM-Derived Mosquito-Repellent Herbs for Primary School Science: Implementation and Practice

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Abstract: *Upper-primary students (grades 4–6) spent five class hours making and testing a mosquito repellent from traditional Chinese medicinal herbs; this paper describes how that interdisciplinary project-based learning (PjBL) unit was designed and taught. The unit grew out of China's 2022 curriculum reform, which asks every subject to set aside time for interdisciplinary thematic learning, and it drew science, mathematics, history, and language arts together around the ordinary nuisance of summer mosquito bites. A four-stage inquiry sequence adapted from the 5E model—phenomenon tracing, evidence-based reasoning, empirical investigation, and conclusion verification—guided the small-group work. Students' worksheets, experimental records, and classroom observations show that they learned to frame testable hypotheses, run experiments with controlled variables, graph quantitative data, and explain unexpected results, and that they came to see a custom such as hanging mugwort at the Dragon Boat Festival as having an empirical basis. The unit template and assessment rubric presented here can be adapted by other primary science teachers, although the sample was small and the measurement was not highly rigorous.*

Keywords: *Interdisciplinary Learning, Project-Based Learning, Scientific Thinking, Primary Science, Traditional Chinese Medicine*

1. Introduction

China's Compulsory Education Curriculum Plan (2022 Edition) says that no less than ten percent of instructional time in every subject should go to interdisciplinary thematic learning [1]. The *Science Curriculum Standard (2022 Edition)* puts scientific thinking and inquiry practice at the centre of its core competencies and tells textbook writers to include ancient Chinese scientific achievements so that pupils come to take pride in their cultural heritage [2]. A further document from the Ministry of Education, the *Guidelines for Integrating Traditional Culture into School Curricula (2021)*, urges science teachers to mine the resources hidden in traditional crafts and old inventions [3]. Taken together, these policies point in the same direction as an international move towards competency-based science education, in which pupils build understanding by working on real problems rather than by absorbing facts handed to them.

The *State Council's Strategic Plan for Traditional Chinese Medicine Development (2016–2030)* likewise wants basic TCM knowledge in school curricula [4]. Educational policy and cultural policy therefore meet in a convenient place, leaving room for science units that tie everyday problems to traditional knowledge. All the same, TCM has not really entered primary science teaching: what exists tends to be cultural appreciation or health education, and herbal crafts such as making repellents are rarely treated as material for inquiry.

Mosquito bites are a summer complaint that nearly every Chinese primary pupil knows at first hand. Synthetic repellents such as DEET and picaridin work, but they can irritate children's skin and airways, particularly when used often or carelessly. Herbal repellents offer an alternative rooted in local practice: texts from the *Rites of Zhou* down to the *Compendium of Materia Medica* mention mugwort, mint, and clove as insect repellents, and phytochemical work has since confirmed volatile compounds with repellent activity in these herbs [5]. Recent studies of compound formulations, for instance mugwort-based liquids and blended essential oils, report measurable repellent effects under controlled conditions [6,7], which makes herbal repellent production a workable context for school science that links cultural

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knowledge to empirical investigation.

Interdisciplinary practice in Chinese primary science classrooms has three persistent weaknesses, whatever the policy documents say. Knowledge is often set side by side rather than integrated around a real problem; pupils follow prescribed procedures without reasoning from evidence, treating experiments as demonstrations; and assessment rewards final products more than thinking. These weaknesses match international findings that inquiry teaching depends on task structure and teacher scaffolding and that unguided discovery fails novice learners [8]. Chinese researchers have looked at interdisciplinary design for scientific thinking [9] and at PjBL applications in primary science, but detailed accounts of a single real problem that holds disciplinary knowledge, structured inquiry, and cultural learning together are still rare. This paper offers such an account: a five-class-hour PjBL unit, for grades 4–6, in which pupils made and tested a TCM mosquito repellent. The conceptual framework is set out in Section 2, the design in Section 3, the implementation and evidence in Section 4, and the discussion and conclusions in Sections 5 and 6.

2. Conceptual Framework

Three bodies of work shaped the unit: project-based learning, the 5E instructional model, and interdisciplinary learning theory.

Project-based learning starts from a driving question, and everything else in the unit follows from it. Pupils investigate, build something, and defend what they have built. PjBL seems to help conceptual understanding and inquiry skills when tasks leave room for reasoning and for teacher scaffolding [8]. In this unit the question was "How can common Chinese medicinal herbs be used to make a safe and effective mosquito repellent?" Answering it pulled pupils across several disciplines, because they had to make the repellent liquid and then back their product with an argument built from their own data. Mosquito bites are a familiar part of pupils' own summers, so the question held their attention over the five hours.

The 5E instructional model (engagement, exploration, explanation, elaboration, evaluation) was developed by the Biological Sciences Curriculum Study and rests on constructivist learning theory; it moves pupils from meeting a phenomenon to explaining it and then applying the explanation elsewhere. For this unit the five phases became four stages—phenomenon tracing, evidence-based reasoning, empirical investigation, and conclusion verification—because upper-primary pupils profit from clearly marked moves between observing, hypothesising, experimenting, and arguing. The merging was not accidental: engagement and exploration collapsed into phenomenon tracing, explanation and elaboration into conclusion verification, and evaluation ran through the whole unit as formative assessment.

Interdisciplinary learning theory says that separate school subjects only become useful to pupils when they are brought together around a shared problem. The repellent problem served that purpose. Instead of treating science, mathematics, history, and language arts as parallel strands, the unit asked pupils to use them together: science for ideas about matter, solubility, and adaptation; mathematics for representing data, averaging, and comparing trends; history for cultural context and for how traditional knowledge accumulates; language arts for writing reports, instruction manuals, and presentations. Integration happened when pupils had to coordinate these ways of working to answer the driving question.

Put together, the three frameworks yielded a design principle: a real problem should sit at the centre of disciplinary knowledge and be the place where scientific thinking moves from observation to an evidence-based conclusion. That principle is what separates the unit from activity-based lessons in which pupils move through a series of tasks without any coherent reasoning behind them.

3. Project Design

3.1 Learning Objectives

Four objectives were written to match the core competencies in the national science curriculum standard. On scientific concepts, pupils would name the main repellent constituents of mugwort, mint, and clove and say what dissolution and filtration do in the soaking process, recognising that volatile substances change insect behaviour, an idea that connects to structure–function relationships in biology

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and chemistry. On scientific thinking, pupils would ground testable hypotheses in observation and prior experience, tell independent, dependent, and controlled variables apart, and design comparative experiments that change only one variable; this objective aimed at the move from concrete to formal operational reasoning that marks upper-primary pupils. On inquiry practice, pupils would carry out the standard operations of chopping, soaking, filtering, dispensing, timing, and counting, and would present data graphically, treating repeated measurement and error awareness as basic habits of investigation. On attitude and responsibility, pupils would set traditional herbal knowledge beside synthetic repellents, observe safety protocols, and learn that empirical testing can confirm or correct inherited practices, so that their respect for tradition became reasoned rather than uncritical.

3.2 Task Structure and Class Hour Allocation

The driving question gave rise to two comparative questions that grew harder in steps: whether mugwort or mint works better as a single-herb liquid, and whether mugwort–mint or mugwort–clove makes the stronger compound. The first comparison let pupils master the basic techniques and establish a baseline; the second carried the inquiry into how combinations change outcomes. This ordering followed a scaffolding logic: pupils first gained procedural competence on the simpler task and then applied it to the harder one. Six tasks made up the chain: tracing the history of herbal repellency, observing the herbs with all the senses, constructing hypotheses, running the two experiments, analysing data and drawing conclusions, and finally producing a finished repellent with an instruction manual. The chain ran from concrete observation to abstract argument. Five forty-minute lessons were used: the first for introduction and herb observation, the second for hypotheses and experimental design, the next two for the experiments, and the last for data discussion, presentations, and the release of the finished products. Pupils worked in groups of four to six, rotating through the roles of materials manager, operator, recorder, and timer so that nobody was stuck in one position.

3.3 The Four-Stage Inquiry Sequence

Table 1 sets the four stages against the thinking progression and the tasks. The sequence worked on two tracks at once: an inquiry track made up of the four cognitive stages, and an experience track made up of herb observation, historical anecdotes, and product design. The two were interwoven rather than separate; when pupils looked at mugwort leaves, for instance, they were at the same time gathering the characteristics that later fed their hypotheses.

Table 1. Four-stage inquiry sequence and scientific thinking progression.

Stage	Core activities	Scientific thinking progression	Tasks
Phenomenon tracing	Herb observation, context introduction, question brainstorming	Observation → questioning	1, 2
Evidence-based reasoning	Hypothesis formulation, principle explanation, hypothesis revision	Hypothesis → reasoning	3
Empirical investigation	Controlled-variable experiments, standardized operation, data collection	Experimentation → verification	4
Conclusion verification	Data visualization, anomaly analysis, presentation and reflection	Evidence → conclusion → critical review	5, 6

3.4 Interdisciplinary Knowledge Integration

Table 2 shows which disciplines each phase drew on and which competencies it targeted. Three lines of integration ran through the unit. The driving question gave the disciplines a shared purpose. The task chain ordered the cognitive demands, moving pupils through tracing, identification, hypothesising, experimenting, verifying, and applying. The evidence chain, from hypothesis to evidence to conclusion, forced pupils to tie their claims to data. In this way knowledge, ability, and values developed in one process rather than as three separate aims.

Table 2. Interdisciplinary knowledge structure of the repellent project.

Phase	Discipline(s)	Key knowledge	Competency
Tracing and herb identification	History, language arts	History of herbal repellency, *Compendium of Materia Medica* records, plant morphology and odor	Cultural appreciation, scientific attitude
Hypothesis construction	Science	Volatile substances, mosquito olfactory perception, variables and control	Scientific thinking
Soaking and extraction	Science	Dissolution and separation, condition control, filtration	Scientific concepts, inquiry practice
Comparative experiment	Science, mathematics	Controlled-variable design, standardized procedure	Inquiry practice
Data analysis	Mathematics	Averages, bar and line charts, trend comparison	Scientific thinking
Product and application	Science, language arts, labor education	Instruction manual writing, safe use	Attitude and responsibility

4. Implementation and Evidence of Learning

4.1 Phenomenon Tracing: Observation and Questioning

The unit began with dried mugwort, mint, and clove on the table and a short video about traditional repellent wisdom. Pupils looked, touched, and smelled. They noticed that mint leaves are bright green and flexible, that clove buds are small, hard, and granular, and that mugwort leaves are silvery underneath and pungent, and they connected the odours to familiar things such as mint candy, which made the abstract idea of volatility tangible. A worksheet asked them to write down what they already knew and what they wondered; the teacher used these answers to judge where to start and to catch misconceptions, the commonest being that a stronger smell always means a stronger repellent. Brainstorming followed, and the teacher's probing questions turned vague curiosity into testable questions. When a pupil asked which herbs repel mosquitoes, the teacher asked back how one would decide; when another asked whether the class could make its own repellent, the teacher raised whether hot and cold water extract the same substances. By the end of the exchange the class had agreed on the two comparative questions, and the teacher had modelled questioning rather than simply answering.

4.2 Evidence-Based Reasoning: Hypothesis Construction

The groups disagreed, and that was useful. Some thought mugwort would beat mint because its smell is stronger and because mugwort has a place in Dragon Boat Festival customs; others backed mint for its sharp, cooling scent. Some expected mugwort–mint to work through complementary odours; others expected mugwort–clove to act faster because clove smells penetrate quickly. The disagreement created a real need for evidence to settle the argument. The teacher then explained how mosquitoes find hosts, mainly through smell, and how volatile herbal odours can overwhelm or confuse that process, using the everyday example of avoiding strong vinegar fumes. The groups went back to their hypotheses and made them more specific about the relation between volatile content and repellency and between combination and compound efficacy. Three criteria for a sound hypothesis were agreed on: it must be centred on a variable, be testable and quantifiable, and connect to prior observation or traditional knowledge. These criteria stayed on the wall and were used to judge each group's reasoning during the experiments.

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4.3 Empirical Investigation: Controlled-Variable Experiments

Experiment 1 compared mugwort liquid, mint liquid, and plain water. The dried herbs were chopped, soaked in 50 mL of room-temperature water for five to ten minutes with occasional stirring, and filtered. Three ventilated observation boxes, each divided into a liquid zone (one third) and a safe zone (two thirds), held five mosquitoes; five drops of each solution were put into the liquid zone with dedicated droppers, and the mosquitoes in the safe zone were counted every two minutes for ten minutes (Table 3). Experiment 2 compared mugwort–mint and mugwort–clove compounds under the same dependent variable and the same controls, carrying the inquiry into formulation effects (Table 4). A uniform counting rule—count once, settle ambiguity by consensus—and repeated measurements where possible introduced the ideas of measurement error and replication. Safety measures included dedicated droppers to avoid cross-contamination, ventilation, careful dispensing, and handwashing afterwards; the mosquitoes came from a biological supply company and were disposed of following biosafety guidelines. The teacher moved between groups, asking questions such as "Is the dropper clean?" and "How do you know the soaking time was the same?" rather than correcting procedures.

Table 3. Design of Experiment 1: single-herb repellent comparison.

Element	Specification
Experimental groups	Mugwort liquid; mint liquid
Control	Plain water (50 mL)
Independent variable	Type of liquid
Dependent variable	Number of mosquitoes in safe zone over 10 minutes
Controlled variables	Water volume (50 mL), soaking time (5–10 min), filtration method, box specifications, mosquito batch and count (5 per box), temperature (~25 ℃), humidity (50–60%), no wind
Equipment	50 mL measuring cups, filter paper, funnels, dedicated droppers, partitioned observation boxes, timer

Table 4. Design of Experiment 2: compound repellent comparison.

Element	Specification
Experimental groups	Mugwort–mint compound; mugwort–clove compound
Independent variable	Herb combination
Dependent variable	Number of mosquitoes in safe zone over 10 minutes
Controlled variables	Mugwort quantity, soaking conditions, filtration, mosquito condition, observation environment
Equipment	Same as Experiment 1

4.4 Outcome Verification: Data Analysis and Anomaly Attribution

The groups pooled their data and drew graphs, bar charts for Experiment 1 and line charts for Experiment 2. In the representative class data, mugwort reached a safe-zone count of four, against two for mint and one for the water control, and mugwort–mint consistently outcounted mugwort–clove, five to three at the ten-minute mark, which suggested that formulation matters. When the data did not behave, the teacher led the groups through attribution. A surprisingly high mint count sent pupils to check whether droppers had been shared or soaking times had drifted; a negligible difference between compounds sent them to ask whether the clove had been under-chopped or under-dosed. These discussions taught pupils that repellent outcomes depend on herb quantity, pretreatment, and extraction conditions, and that careful experimental habits are themselves a form of empirical rigour.

4.5 Learning Outcomes and Assessment

Four kinds of outcomes came out of the unit. There were products: the repellent samples and the instruction manuals in which pupils wrote up ingredients, use, and safety. There were thinking artifacts: charts, experimental reports, and records of anomaly attribution that showed the pupils' reasoning. There were communication outcomes: the group presentations in which each group explained its hypothesis, methods, results, and conclusions. And there were cultural products: hand-drawn timeline posters on the history of herbal repellency and handmade sachets that carried the theme beyond the experiments. In the presentations pupils tied observations to evidence. One group pointed out that mugwort's stronger smell went with a higher safe-zone count, giving empirical support to the habit of

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hanging mugwort; another concluded that not every combination improves repellency and that pretreatment and dosage matter, a lesson they connected to the TCM idea of choosing a processing method to suit the herb. Assessment ran through a six-dimension performance rubric (Table 5), each dimension with three proficiency levels, combining self-assessment, peer assessment, and teacher judgment. The rubric was handed out at the start to clarify goals, used during lessons for formative feedback, and applied at the end for summative assessment.

Table 5. Performance assessment rubric.

Dimension	Level 1	Level 2	Level 3
Question posing	Raises theme-related questions	Converts vague questions into investigable ones	Poses variable-directed, operational scientific questions
Experimental design	Restates the plan	Identifies independent and dependent variables	Designs controlled-variable comparative plans
Standardized operation	Completes tasks with guidance	Follows procedures accurately	Anticipates details such as cross-contamination and adjusts
Evidence-based reasoning	Describes data	Represents data in charts	Compares, attributes, and revises conclusions from evidence
Collaborative communication	Participates in group work	Fulfills roles and records data	Presents clearly and responds to questions
Cultural appreciation	Knows repellent herbs	Gives examples of traditional repellent practices	Empirically understands and values TCM culture

5. Discussion

Three findings stand out. First, the unit managed real disciplinary integration. The same problem called on scientific ideas of solubility and volatility, on mathematical work with averages and graphs, on historical knowledge of TCM, and on written communication, and the integration showed up in what pupils produced, not just in the teacher's plan. This is in line with international work on interdisciplinary STEM learning, which holds that integration works best when disciplines meet on a shared task.

Second, the four-stage sequence made scientific thinking visible. Pupils moved from observing herbs to formulating variables, from running controlled experiments to interpreting data and explaining anomalies, and hypothesis revision and anomaly attribution opened windows into their reasoning that routine cookbook experiments do not. Giving the stages names gave pupils words to talk about their own thinking, a kind of metacognitive scaffolding that is often missing in primary science, and it fits the evidence that inquiry learning benefits from structured guidance rather than unguided discovery [8].

Third, the cultural dimension rested on evidence rather than assertion. Pupils did not just learn that mugwort is traditionally used; they collected data linking odour, volatile constituents, and repellent behaviour, and moved from accepting the tradition on authority to understanding it through scientific reasoning, a distinction that matters for science education and cultural education alike.

Several limitations qualify these findings. The experiments were simplified for teaching: the safe-zone count is a coarse indicator, each box held only five mosquitoes, and the results describe the classroom conditions alone. Proper evaluation would follow a standard such as *GB/T 13917.9—2009* [10]. Warm-water extraction captures only part of the fat-soluble volatile oils, and comparisons with alcohol soaking or steam distillation would deepen pupils' understanding of extraction. Time pressure limited the manual and the extension activities, which could be moved to after-school clubs; schools with fewer resources would have to adapt the herbs, containers, and observation methods. Finally, the rubric has not been tested for reliability or validity on larger samples.

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6. Conclusions

This paper has described an interdisciplinary PjBL unit in which upper-primary pupils made and tested a TCM mosquito repellent. An everyday problem brought the disciplines together, structured a four-stage inquiry, and joined cultural knowledge to empirical investigation, and the classroom evidence shows pupils gaining ground in hypothesis formulation, controlled experimentation, data visualisation, and evidence-based reasoning, along with a reasoned view of herbal practices. Two things may be of use to other teachers. The four-stage dual-track sequence and the six-task chain form a transferable template for similar units, such as handmade sachets, natural pigment extraction, or traditional food preservation. And the three-level rubric offers a way to assess thinking processes rather than only finished products, a weakness common in project-based teaching. Future work should measure learning outcomes more strictly, with pre- and post-tests of scientific reasoning, and should look at how the unit adapts to other grades and school settings. Research on how teachers learn to lead structured inquiry would also be useful, since such units depend heavily on teacher questioning and scaffolding, and it would show whether the patterns observed here hold for wider populations.

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