A Systematic Exploration of Designing Project-Based Assignments for Junior High School Science: Principles, Strategies and Case Studies

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ABSTRACT

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| With the curriculum reform oriented toward core competencies, traditional junior high school science teaching models have gradually exposed deficiencies of emphasizing theory over practice and knowledge over abilities. This paper focuses on the application of project-based assignments in junior high school science teaching, systematically reviews their theoretical foundations, research progress, advantages and challenges. It proposes a design framework and implementation strategies based on principles of inspiration, comprehensiveness, and authenticity. Through case analysis, this paper uses “unveiling the secrets of combustion—home kitchen fire safety action” as a theme to demonstrate how project-based assignments cultivate students’ scientific inquiry abilities, innovative thinking, and social responsibility through driving questions, task chain design, interdisciplinary integration, and diversified evaluation systems. Research shows that project-based assignments can effectively enhance students’ learning interest and comprehensive abilities, but their implementation still faces challenges in terms of time, resources, and evaluation. This paper provides educators with operational design strategies and practical pathways, and offers suggestions for future research directions. |

*Keywords:* *Project-based assignments; junior high school science; assignment design; driving questions.*

1. INTRODUCTION

Junior high school science education is a critical component of students’ overall development, influencing their cognitive and social skills. It transcends the mere transmission of scientific knowledge; it is essential for fostering scientific thinking and enhancing practical problem-solving skills among students. As educational reforms progress, traditional science education models have increasingly shown significant deficiencies, particularly in their tendency to prioritize rote knowledge over skill development and theoretical understanding over practical application. Consequently, enhancing the effectiveness of science teaching—especially through the integration of practical and innovative approaches in science assignments—has emerged as a pivotal concern for educators and researchers alike.

In this context, project-based assignments (PBAs) have gained traction as a promising educational approach that aligns with contemporary pedagogical goals. PBAs are rooted in the principles of project-based learning (PBL), designed to facilitate inquiry-based learning through authentic, comprehensive project tasks. This approach emphasizes the application of knowledge, problem-solving, and the demonstration of outcomes, thereby nurturing students’ creative thinking and practical problem-solving abilities. This model is particularly well-suited for science education, as science inherently involves inquiry and experimentation, making it an ideal context for PBAs. By integrating theoretical knowledge with hands-on activities through a “learning by doing” approach, PBAs effectively cultivate students’ scientific literacy, inquiry skills, and practical competencies. This educational approach aligns closely with the objectives outlined in China’s “Compulsory Education Science Curriculum Standards (2022 edition),” which emphasize the cultivation of core competencies through inquiry-based activities in authentic contexts. These standards advocate for students to actively construct knowledge systems and develop scientific thinking skills through hands-on practice and inquiry (Ministry of Education of the People’s Republic of China, 2022).

2. Research Progress on Project-Based Assignments

**2.1 Origin of Project-Based Assignments**

The concept of project-based assignment originates from project-based learning, which can be traced back to the early 20th century. It was first advocated by American educator John Dewey, who proposed the educational philosophy of “learning by doing”, believing that learning should start with students’ interests and curiosity, and that students should gain genuine understanding and knowledge through participation in actual activities (Dewey, 2024). This philosophy laid the foundation for later constructivism learning theory. Constructivism emphasizes that learning is an active process of knowledge construction, where students gradually form deep understanding of knowledge through interaction with the environment and social collaboration. However, project-based learning as a teaching method gained widespread recognition and adoption in the 1990s, particularly in primary and secondary education in western countries such as the United States and Canada.

Project-based assignment, as an important component of PBL, have received considerable attention for their ability to effectively promote the cultivation of students’ core competencies. In recent years, project-based assignments have been gradually adopted by many schools and educational institutions worldwide, particularly in STEM (Science, Technology, Engineering, and Mathematics) education and interdisciplinary curricula, becoming an important assignment approach. In project-based assignments, students apply scientific knowledge to authentic contexts through designing experiments and solving problems, thereby achieving deep learning. This method not only aligns with the core ideas of constructivism but also cultivates students’ critical thinking and innovative abilities (Chiang, & Lee, 2016; Putri, et al., 2019; Sari, et al., 2024).

**2.2 Current Research Status of Project-Based Assignments**

The American educational community first integrated project-based learning concepts into assignment design, emphasizing problem-oriented and sustained inquiry. Cooper reviewed the changes in attitudes and concepts regarding homework since the 20th century, from the era when homework was considered beneficial for mental exercise to questioning its actual benefits for students, revealing a significant transformation in educational concepts. This transformation is related to the rise of project-based learning, as PBL focuses more on practice and experience rather than traditional memorization and repetition. Cooper’s empirical research showed that project-based assignments can significantly enhance students’ problem-solving abilities through authentic task-driven approaches (such as community environmental surveys) (Cooper, 1989; Cooper, et al., 2012). Krajcik et al. proposed that project-based assignments should center on driving questions, emphasizing the authenticity and openness of tasks while highlighting student collaboration and inquiry (Krajcik, et al., 1998; Krajcik, & Czerniak, 2018). Subsequent research has mainly focused on exploring the impact of project-based assignments on student ability development, showing that project-based assignments can significantly enhance students’ creativity, comprehension, and interdisciplinary thinking abilities (Mahdiyah, 2022; Eliaumra, 2025).

Research on project-based assignments in China started relatively late, but in recent years, with the implementation of the “Double Reduction” policy and core competency-oriented curriculum reform, project-based assignments have gradually gained attention. According to search results from the CNKI (China National Knowledge Infrastructure) database, domestic research on project-based learning has shown a steady upward trend since 2016.

Domestic research mainly focuses on the application of project-based assignments in subject teaching. Applications of project-based assignment design can be seen in various subjects such as physics, chemistry, geography, and biology. These project-based assignment designs all reflect the requirements for assignment design under the “Double Reduction” policy, namely conforming to age characteristics and learning patterns, embodying quality education orientation, and encouraging stratified, flexible, and personalized assignment design. For example, using actual projects such as “mini solar cars” (Chen, & Li, 2024) and “catapults” (Yu, et al., 2024) to guide students to focus on life and society, achieving transformation from basic physics knowledge to extended application, from material classroom to practical application. In chemistry teaching, by designing project-based assignments that meet curriculum standard requirements, solve real problems, and possess inquiry and generative characteristics, assignments play a positive role in diagnosing learning situations, providing teaching feedback, and controlling teaching. In geography teaching, project-based assignment design is conducted by relying on actual venues such as parks to determine project themes and assignment objectives. In biology teaching, using the project assignment of “designing hydroponic devices for home vegetable cultivation” (Wang, et al., 2024) as an example, the design and implementation of project-based assignments based on improving students’ core competencies and achieving the goal of reducing burden and increasing efficiency were explored.

3. Advantages and Challenges of Project-Based Assignments

In junior high school science teaching, implementing project-based assignments has significant advantages but also faces some challenges.

**3.1 Advantages**

**3.1.1 Deepening understanding and knowledge application**

Project-based assignments typically require students to apply learned knowledge to practical problems, promoting deep understanding and flexible application of scientific concepts. For example, through designing a simple circuit or creating an ecosystem model, combining hands-on practice with deep thinking, students can better understand abstract concepts such as electric current and energy flow, as well as verify variable relationships through multiple experiments, understanding the nature of science through trial and error.

**3.1.2 Cultivating comprehensive abilities**

The core value of project-based assignments lies in transcending mechanical memorization of knowledge points and shifting toward cultivating students’ comprehensive abilities to solve complex problems. By setting authentic driving questions such as “How can we make light bulbs both bright and energy-efficient?” or “Exploring environmental protection solutions for Earth”, it guides students through a complete inquiry cycle: from information collection, problem analysis, and solution design to final outcome presentation and reflection, cultivating students’ scientific inquiry abilities, critical thinking, creativity, and problem-solving skills. Project-based assignments encourage students to comprehensively apply multidisciplinary knowledge and solve complex problems through autonomous inquiry, helping to establish connections between disciplines. For example, students can combine environmental science and sociology in chemistry projects to study plastic pollution problems and propose solutions. A project on “climate change” requires integrating knowledge from multiple fields including science, mathematics, geography, and technology. The “seawater salt production” project integrates content from multiple disciplines including physics (evaporation, crystallization), chemistry (substance separation), and even geography (marine resources). This design not only breaks down disciplinary barriers, enabling students to comprehensively apply knowledge in authentic contexts, but also echoes the “cross-cutting concepts” and “science and engineering practices” frameworks emphasized in international curriculum standards such as NGSS and CCSS, helping to cultivate innovative talents with international perspectives.

**3.1.3 Stimulating learning interest**

Project-based assignments typically use practical problems or authentic contexts as backgrounds, helping students connect scientific knowledge with daily life, stimulating their curiosity and desire for exploration, and enhancing the practical significance of learning. Research shows that project-based learning can significantly improve students’ learning motivation and engagement, especially in STEM fields. For example, having students design a water-saving device or study local environmental pollution problems can help them feel the practicality and significance of science. Oduro et al. reviewed consolidates qualitative and mixed-methods evidence on K-12 students’ perceived efficacy of project-based instructional models (Oduro, et al., 2024).

**3.2 Challenges**

**3.2.1 Time and resource constraints**

A complete project-based assignment, from preliminary design, material preparation, process guidance to outcome evaluation, often requires spanning multiple class periods or even weeks, creating sharp conflicts with the current fixed teaching schedules and class arrangements in junior high schools. Teachers have almost no substantial blocks of time to invest in high-intensity project-based teaching beyond their heavy regular teaching tasks. As a coping strategy, some research suggests breaking down large projects into phased mini-projects that align with regular teaching cycles.

Resource scarcity is another major obstacle. Many junior high schools lack necessary experimental equipment, instruments, venues, model-making tools, consumables, and external experts, and schools’ limited funding cannot support large-scale, normalized implementation of project-based assignments. In response, some research suggests flexible solutions through integrating social capital, such as seeking cooperation from parents, community enterprises, or universities to provide materials or expert guidance.

**3.2.2 Significant evaluation difficulties**

The outcomes of project-based assignments, such as investigation reports and creative designs, are diverse, making evaluation standards difficult to unify. How to scientifically and fairly evaluate students’ performance in project-based assignments is another major challenge teachers face. Teachers need to develop diversified evaluation methods, such as formative assessment and performance assessment, to comprehensively reflect students’ learning outcomes. Evaluation should not only focus on final tangible outcomes but also encompass students’ cognitive development, collaborative abilities, and depth of reflection throughout the entire inquiry process. To this end, educators have developed various evaluation methods, such as multiple evaluation tools, including multi-dimensional PTA scales that break down projects, performance assessments containing outcome presentations, on-site defenses, and peer evaluations, as well as whole-process portfolios that record students’ cognitive development curves, and developmental evaluation that emphasizes providing students with confidence-building feedback through real-time observation and verbal encouragement during the process, focusing on their growth trajectory rather than endpoints.

In comprehensive scoring, the weight allocation between process performance (such as participation and teamwork) and outcome results (such as scientific rigor and completeness) becomes a key point of controversy, with evaluation weight settings relying more on teachers’ educational philosophies and negotiations with students.

**3.2.3 Student ability differences**

Different students have varying learning abilities, foundations, and interests, and project-based assignments may create pressure for students with weaker learning foundations. It is necessary to design tiered tasks to accommodate different students’ needs. Additionally, not all students are interested in project-based assignments; some students may prefer traditional assignment formats, leading to low participation.

**3.2.4 Teacher guidance capabilities**

Successfully implementing project-based assignments requires teachers to transform their role from knowledge transmitters to learning designers, facilitators, and technical coordinators. This places higher demands on teachers’ curriculum design abilities, project management skills, interdisciplinary knowledge reserves, and evaluation literacy. Some teachers may lack relevant training, leading to unscientific project design or poor implementation effects. If teachers lack relevant experience, they may find it difficult to effectively support students’ project development.

In summary, project-based assignments are powerful tools for cultivating core competencies in junior high school science teaching, but their implementation also faces certain challenges. Only by facing challenges squarely and solving them in a targeted manner can their educational value be maximized, enabling science education to move from knowing to doing. To fully leverage their role, it is recommended that in junior high school science teaching, the design of project-based assignments should be based on educational objectives, subject characteristics, and students’ cognitive development as core criteria, following the following core principles to ensure that projects both align with the essence of science education and match junior high school students’ ability levels.

4. Principles of Project-Based Assignment Design

Designing effective project-based assignments requires ensuring that projects are both educationally meaningful and capable of stimulating students’ interest and engagement. The following are principles for designing effective project-based assignments in junior high school science teaching, which reflect the basic requirements of educational concepts and teaching principles.

**4.1 Principle of Inspiration**

Assignment design should stimulate students’ curiosity and desire for inquiry, guiding students to learn actively through problem-driven approaches. For example, designing open-ended questions such as “How can we reduce the campus carbon footprint?” encourages students to find solutions through investigation and experimentation. Emphasis should be placed on guiding students through complete scientific inquiry processes including observation, questioning, experimentation, and data analysis, rather than directly instilling conclusions. Allow trial and error and iterative improvement, encouraging students to develop critical thinking and innovative abilities in uncertainty. For example, allowing experimental failures and analyzing causes.

**4.2 Principle of Comprehensiveness**

Project-based assignments should integrate multidisciplinary knowledge, break down subject barriers, and help students establish interdisciplinary knowledge connections. For example, designing bridge models requires combining mechanical principles with aesthetic design; combining physics, chemistry, and biology knowledge to design interdisciplinary projects such as “home energy conservation plans”. Meanwhile, project-based assignments should enhance comprehensive abilities, focusing on cultivating 21st-century core competencies such as communication and collaboration, data processing, and technology application.

**4.3 Principle of Authenticity**

Project-based assignments should be connected to real-world problems, with content close to students’ actual lives, emphasizing practical operations and applications in authentic contexts, enhancing students’ ability to solve practical problems, and enabling students to feel the meaning and value of learning. For example, designing projects such as “How to improve community waste sorting” allows students to propose improvement suggestions through field research and data analysis; designing projects such as “How to improve local water quality” places knowledge in specific contexts for application, giving students the social identity of environmental engineers, allowing students to simulate scientists’ processes for solving practical problems (observation → hypothesis → verification → conclusion), proposing scientific suggestions through experimentation and data analysis, and enhancing the transfer value of learning.

**4.4 Principle of Student Agency**

Students are active participants and constructors of projects, with teachers serving only as facilitators and supporters. Project-based assignment design should be student-centered, respecting students’ individualized needs. Projects should encourage students to independently select topics, plan, implement, and reflect, granting them decision-making power and responsibility. For example, respecting students’ interests by allowing them to choose research topics based on their interests and independently formulate project plans; respecting differences in students’ abilities and learning paces by allowing them to choose different research directions according to their capabilities, such as students choosing to study “the impact of plastic pollution” or “innovative methods to reduce plastic use”; allowing diversified solutions and forms of expression, such as experimental reports, model making, digital works, etc. Teachers only provide precise support in cognitive blind spots, not answering “what to do” but guiding “what tools/methods are available”, such as suggesting the controlled variable method when data is chaotic.

**4.5 Principle of Assessability**

Project-based assignment design should include clear evaluation criteria to facilitate teachers’ scientific assessment of students’ learning processes and outcomes. For example, designing diversified evaluation methods, including formative and summative assessments, establishing evaluation systems that encompass dimensions such as knowledge mastery, practical skills, innovative consciousness, and collaborative attitudes, avoiding single-score approaches.

**4.6 Principle of Clear Objectives**

Project-based assignments must precisely align with curriculum standards, closely corresponding to knowledge points, skill points, and core competency requirements in curriculum standards, avoiding becoming mere craft activities and ensuring the realization of educational value. For example, when designing a “wind turbine model” project, it should focus on the core concept of “energy conversion”, with the core objective being understanding the “kinetic energy → electrical energy” conversion mechanism, rather than merely pursuing model appearance.

These principles constitute the underlying logical framework for project-based assignment design, ensuring they both align with the essential laws of science education and adapt to junior high school students’ physical and mental development stages. Teachers need to flexibly balance these principles in practice, avoiding mechanical application. For example, emphasizing authenticity while considering safety, and maintaining scientific rigor while encouraging innovation.

5. Strategies for Project-Based Assignment Design

When designing project-based assignments, design principles need to be transformed into operational action pathways. The following are specific design strategies, focusing on operational methods and techniques to help teachers transform design concepts into practice.

**5.1 Project Conceptualization and Context Creation Strategies**

The starting point of project-based assignments is crucial, as it directly determines students’ participation motivation and depth of inquiry. Successful project design begins with careful preliminary conceptualization and context creation.

Project-based assignments need to abandon straightforward enumeration of knowledge points and instead design a challenging, open-ended, and inquiry-valuable driving question to govern the entire project. This question should effectively stimulate students’ curiosity and guide them in sustained inquiry. Driving questions should originate from students’ real-life experiences or social hotspots, making them practically meaningful. For example, when learning about buoyancy, instead of directly assigning calculation problems, pose grand contextual questions such as “How does the ‘Fujian’ aircraft carrier float on water, and how much weight can it carry?” to connect unit knowledge. In the circuit unit, one can design “How to design an energy-efficient and safe warning light for night running enthusiasts?”

A good driving question typically has no unique answer and requires students to comprehensively apply multidisciplinary knowledge through various methods such as investigation, research, experimentation, and argumentation to explore solutions. For example, the project “How can we effectively reduce plastic waste around us?” drives students to research plastic composition, environmental impact, alternative materials, and other sub-questions. When learning about “ecosystems”, transform “biodiversity surveys” into “diagnosing causes of ecological degradation in campus groves and restoration proposals”, investigating real variables such as invasive species and soil pH levels.

Project-based assignments should be firmly anchored in authentic contexts that students can perceive and understand. Context is not only the background for knowledge application but also the field where learning occurs. Selected contexts need to be close to students’ lives, possessing practicality and operability. For example, “designing a hydroponic device for vegetable cultivation on home balconies” directly relates to family life and biological knowledge, allowing students to intuitively see the value of their learning outcomes. Similarly, “making a wind vane that can accurately indicate wind direction” or “designing an ultra-long-lasting ecological aquarium” are effective contexts that closely combine scientific principles with hands-on practice. When constructing contexts, teachers need to vividly present situations through stories, videos, news reports, and other means, creating immersion and a sense of mission to solve problems. Context construction aims to help students understand why to learn, thereby stimulating intrinsic learning motivation.

**5.2 Task Decomposition and Scaffolding Strategies**

If a project is not structurally processed, students will feel at a loss. Therefore, decomposing complex tasks and providing necessary support is key to project success. Driving questions can be decomposed into a series of interconnected, progressively difficult, and gradually deepening sub-tasks, forming a clear task chain. The “major task + scaffolding minor tasks” model is a very practical model, with one driving major task as the overall project goal, decomposed into several scaffolding minor tasks, each paving the way for completing the major task. For example, in the “energy-efficient night running light” project, minor tasks can include: researching night running lights on the market, learning about series and parallel circuit knowledge, selecting appropriate light sources and power supplies, drawing circuit diagrams, making models, testing and improving, etc.

Task chain design should pay attention to gradients, following cognitive patterns from basic knowledge review to core concept exploration, then to comprehensive application and innovation. This ensures that students’ abilities and knowledge levels can progress step by step during task completion, always remaining in the zone of proximal development.

Project-based assignments naturally possess interdisciplinary attributes. Design should consciously break down subject barriers, organically integrating scientific knowledge with other subject content to construct comprehensive knowledge networks. For example, in the “initial exploration of ‘Fujian’ ship” project, students not only need to use physics principles of buoyancy but also need to apply mathematical knowledge for volume, mass, and density calculations, and may even need to use information technology for modeling and data collection. In the “design an eco-friendly water bottle” project, students need to integrate scientific knowledge (material properties, structural mechanics), mathematical knowledge (volume calculation), artistic knowledge (aesthetic appearance design), and even social science knowledge (market research, cost analysis). This integration strategy helps students realize that solving real-world problems often requires comprehensive abilities.

**5.3 Strategies for Meeting Individualized Learning Needs**

Individual differences exist among students, and project-based assignment design must fully consider this to enable every student to grow through projects. Tiered assignment design is an effective strategy widely validated in subjects such as physics and chemistry, aimed at providing tasks of different difficulty and complexity for students at different learning levels.

Teachers can tier by difficulty, designing three levels of project tasks: basic, semi-comprehensive, and comprehensive. For example, in physics, basic tasks might focus on applying single knowledge points; semi-comprehensive tasks require applying knowledge from one unit; while comprehensive tasks might need cross-unit, interdisciplinary knowledge integration. They can also tier by roles, assigning different roles in group projects based on students’ strengths and interests, such as project manager, experimental operator, data analyst, report writer, etc., allowing each student to leverage advantages and contribute value. Teachers can also provide tiered resource packages with three difficulty levels of support materials: red basic version (with detailed steps), blue standard version (highlighting key nodes), black challenge version (providing only reference bibliography). Meanwhile, teachers should provide certain choice spaces in task design, allowing students to choose research focus or outcome expression methods based on their interests, thereby stimulating initiative.

Additionally, project-based assignments are typically conducted in groups, which itself is a strategy for addressing differentiation. Through scientific grouping and clear division of labor, mutual assistance and intellectual collision among students can be promoted. Teachers should group scientifically, considering factors such as students’ knowledge levels, hands-on abilities, and personality characteristics for heterogeneous grouping, ensuring relatively balanced member composition in each group and avoiding star groups or lagging groups. Group size is recommended to be 4-6 people for ease of management and collaboration.

**5.4 Teacher Guidance and Resource Empowerment Strategies**

During project implementation, teachers’ roles and resource provision methods also need to adopt specific strategies to ensure smooth project progress.

Teachers need to transform from knowledge transmitters to learning facilitators, promoters, and resource providers. Teachers need to closely observe each group’s progress during collaboration, provide scaffolding support at key nodes, guide students in effective communication and discussion, and resolve potential conflicts. For example, when students’ inquiry direction deviates, guide them back on track through questioning; when students encounter technical difficulties, provide necessary resource clues or operational demonstrations. Feedback should be timely, specific, and focused on the learning process rather than just results. Teachers should encourage students to reflect during inquiry, independently discover problems and optimize solutions, ensuring that collaborative inquiry doesn’t remain at the surface level but truly achieves intellectual collision and mutual progress. For example, in the “wind vane making” project, when students discover problems after testing, teachers should guide them to analyze causes and independently propose improvement measures rather than directly providing correct answers.

Furthermore, completing project-based assignments cannot rely solely on textbooks; strategies must be adopted to integrate various resources both inside and outside school, online and offline. Teachers should guide students in proficiently using information technology tools such as office software, image processing software, and simulation programs for data processing, outcome presentation, and solution design. Teachers should also strategically utilize social resources, such as organizing student visits to science museums, museums, and corporate laboratories, or inviting experts from relevant fields for online lectures, using online cloud classrooms and other methods to broaden students’ horizons. Through parent meetings, project outcome exhibitions, and other forms, actively integrate family resources to form synergy between home and school education, helping parents understand and support students’ project-based learning.

**5.5 Strategies for Constructing Diversified Evaluation Systems**

Assessment of project-based assignments cannot continue using single paper-and-pencil tests; a diversified assessment strategy that comprehensively and authentically reflects students’ ability development must be adopted. Evaluation should run throughout the project, combining formative assessment (process evaluation) with summative assessment (outcome evaluation), focusing on students’ performance throughout the entire process, not just final outcomes. Formative assessment focuses on evaluating students’ participation, collaborative spirit, inquiry abilities, thinking patterns in problem-solving processes, etc., which can be conducted through classroom observation, group interviews, learning journals, and other methods. Summative assessment evaluates the quality of final project outcomes (such as reports, models, presentations, etc.). Only by combining both can students’ learning effectiveness be comprehensively reflected.

To achieve comprehensive evaluation, teachers need to strategically design and use various assessment tools. Rubrics are one of the most core evaluation tools in project-based learning. Teachers can jointly develop evaluation rubrics with students, clarifying specific standards for each evaluation dimension (such as scientific concept understanding, inquiry process, teamwork, outcome presentation) and performance descriptions for different levels. This serves not only as the basis for evaluation but also as a guide for students to clarify their direction of effort. Taking scientific practice ability as an example, decomposing ability dimensions and designing specialized rubrics, as shown in Table 1 below:

**Table 1 Scientific practice ability evaluation rubric**

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| --- | --- |
| **Evaluation dimension** | **Evaluation level** |
| **L1 (Basic) → L4 (Excellent)** |
| Experimental design | Imitative operation → Independent control of multiple variables |
| Data analysis | Describing phenomena → Establishing models to explain correlations |
| Critical reflection | Pointing out errors → Proposing systematic optimization plans |

Teachers can also design a series of checklist and table tools such as project practice ability assessment form, project outcome evaluation form, and project knowledge testing form to conduct quantitative or qualitative assessments of abilities in different dimensions, as well as evaluate the achievement of core competencies such as scientific explanation and model construction by designing specific task contexts and observing students’ actual behavioral performance when solving problems.

When designing project-based assignments, teachers should introduce multi-stakeholder participation in evaluation, changing the traditional model of teachers as sole evaluators, introducing student self-assessment and peer assessment to form a three-dimensional evaluation network. After project completion, guide students to conduct self-reflection and evaluation against evaluation rubrics, and evaluate peers’ contributions and outcomes. This not only reduces teachers’ evaluation burden but also cultivates students’ reflective abilities and sense of responsibility. The combination of teacher evaluation, self-evaluation, and peer evaluation makes evaluation results more objective and comprehensive.

The design of junior high school science project-based assignments is a systematic project, and its successful implementation depends on the above series of interlocking strategies. From forward-looking strategies initiated by driving questions to structured strategies centered on task chains and interdisciplinary approaches; from differentiated strategies of tiered design meeting individual needs to process strategies where teachers play the role of facilitators and integrate multiple resources; to finally adopting evaluative strategies of evaluation rubrics and multi-stakeholder participation, these together constitute a complete methodology. Teachers should flexibly apply these strategies in practice, making adjustments and innovations based on specific teaching content, student characteristics, and realistic conditions, thereby truly leveraging the educational value of project-based assignments and promoting deep development of students’ scientific core competencies.

6. Case Study of Junior High School Science Project-Based Assignment Design

Combustion is an important content in junior high school science curricula. This topic encompasses multiple essential scientific concepts including chemical reactions, energy conversion, and environmental impacts, making it an ideal subject for comprehensive scientific inquiry. This project-based assignment taking “unveiling the secrets of combustion” as its theme stems from several key factors:

First, combustion phenomena are ubiquitous in students’ daily lives, from cooking and heating to transportation and industrial processes. This real-world relevance creates authentic learning contexts that can significantly enhance student engagement and understanding. Second, through project-based assignments focused on combustion, students can systematically explore combustion conditions, phenomena, and environmental impacts while developing crucial scientific inquiry abilities. Third, this thematic approach allows students to connect theoretical knowledge with practical applications, thereby cultivating their comprehensive scientific literacy.

We believe that by combining actual combustion phenomena from everyday life with carefully designed inquiry tasks, this theme provides an optimal framework for guiding students through experimental investigation and scientific knowledge acquisition. The choice reflects both pedagogical effectiveness and curricular alignment with educational standards.

**6.1 Design Philosophy**

The design core of this project-based assignment is authenticity and comprehensiveness. We abandoned isolated knowledge point transmission and instead chose an authentic context closely related to students’ lives with significant warning significance— “home kitchen oil pan fire” —and transformed it into a challenging driving question that runs throughout the project.

In design, authentic problems stimulate students’ intrinsic inquiry desire and sense of mission to solve problems, emphasizing that students personally experience the complete process of scientific inquiry through hands-on experiments, comparative analysis, collaborative discussion, and other methods, autonomously constructing deep understanding of combustion conditions. Closely combining scientific principle learning (combustion conditions) with life practical skill cultivation (fire extinguishing methods, fire escape), enabling students to learn through doing and comprehend through using. All project components point toward clear core competency goals and comprehensively assess students’ knowledge, abilities, and emotional attitudes through process-oriented, diversified evaluation methods.

**6.2 Project Theme and Objectives**

We set the project theme as: unveiling the secrets of combustion—home kitchen fire safety action. The final project outcome to be completed is: each group needs to create a home kitchen fire safety guide for community neighbors, with unlimited formats, which can be promotional posters, popular science short videos, safety manuals, interactive H5 pages, or a popular science toolkit containing demonstration experiments.

The project’s knowledge and skill objectives are: through experimental inquiry, accurately state the three necessary conditions for combustion; understand and explain the basic principles of fire extinguishing, and list correct handling methods for at least three different types of fires; master correct escape methods and alarm protocols in fires (especially smoky environments); learn to design and execute comparative experiments, and analyze and summarize experimental phenomena.

Process and method objectives are: experience the complete scientific inquiry process from problem discovery and analysis to solution design and problem-solving; learn group collaboration, effective division of labor, communication, and cooperation; cultivate abilities in information collection, processing, integration, and innovation, and demonstrate outcomes in diversified forms.

Emotional attitude and value objectives are: recognize the important application value of scientific knowledge in life, enhance interest in learning science; establish safety first awareness, strengthen fire safety and social responsibility; cultivate rigorous and realistic scientific attitudes and spirits of daring to question and innovate in inquiry activities.

**6.3 Driving Question Design**

To effectively drive the entire project, we designed a driving system consisting of one core driving question and a set of tiered question chains. The core driving question is: “If we are community safety guardians, how should we design and create a vivid and effective home kitchen fire safety guide to reveal the secrets of combustion to community residents, and teach everyone how to scientifically and calmly respond to emergencies like oil pan fires?” This question design balances authenticity (community safety), challenge (design and creation), and applicability (popular science promotion), providing students with clear roles, tasks, and target audiences.

The tiered question chain includes the first level: foundational questions (knowledge input and understanding), namely what exactly is “combustion”? Which phenomena in our lives belong to combustion? Through consulting materials and watching videos, what conditions can we preliminarily infer are needed to light a candle? In the video, why does an oil pan suddenly catch fire? Why do firefighters strictly prohibit using water to extinguish oil pan fires?

The second level is application questions (experimental verification and principle transfer), namely how to design one or a group of convincing comparative experiments to verify our hypothesis about what conditions combustion requires? Since we know the conditions for combustion, what are the principles of fire extinguishing? What small experiments can we design to simulate fire extinguishing methods such as covering with a lid, covering with wet cloth, and turning off gas? If the fire cannot be controlled, how should we protect ourselves? What golden rules must be followed when escaping in smoke-filled corridors?

The third level is innovative questions (comprehensive design and outcome creation), namely how to present the scientific principles we have explored to community residents in the most accessible and attractive way? For example, creating an animation of fire extinguishing principles or designing a hands-on operational model? What core sections should our kitchen fire safety guide include? For example, high-risk behavior checklist, combustion principle diagrams, correct fire extinguishing methods, wrong practice warnings, escape route planning, emergency contact numbers, etc. How to evaluate the scientific rigor, practicality, and creativity of our group’s work? What standards can we establish?

**6.4 Project Implementation Process and Activity Design**

This project is specifically divided into four closely connected stages.

**6.4.1 Stage one**

Stage one is context creation and project initiation, including three activities, as detailed in Table 2

**Table 2 Stage one activities**

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| --- | --- |
| **Activity No.** | **Activity content** |
| Activity one:  context impact | Teachers play a carefully edited real news report or simulation video about home kitchen oil pan fires, including the moment of ignition, explosion phenomena caused by incorrectly using water to extinguish fires, and correct handling methods.  Guide students to share viewing experiences, raise questions, and naturally introduce the foundational question chain. |
| Activity two:  project launch | Teachers formally announce the core driving question, clarifying project tasks, roles, and final outcome requirements.  Display excellent project works from previous years (if available) to stimulate students’ creative enthusiasm and confidence. |
| Activity three:  team formation | Students freely combine to form 4-5 person “community safety guardian” project groups.  Each group conducts preliminary discussions, brainstorms around the driving question, forms preliminary inquiry plans and task divisions, such as research group, experiment group, design group, etc., and fills out project initiation plans. |

**6.4.2 Stage two**

Stage two is autonomous inquiry and experimental verification, including three activities, as detailed in Table 3. This stage is the core inquiry component of the project, emphasizing students’ hands-on practice and deep thinking.

**Table 3 Stage two activities**

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| --- | --- |
| **Activity No.** | **Activity content** |
| Activity one:  knowledge construction | Each group uses resources such as internet and books to autonomously learn basic knowledge about combustion definition, classification, combustion products, etc., around the foundational question chain. |
| Activity two:  core experiment—exploring combustion conditions | Objective: Through comparative experiments, verify that combustion requires three conditions: combustible material, contact with oxidizer (oxygen), temperature reaching ignition point.  Experimental design: Teachers provide basic equipment, encouraging each group to improve upon classic experiments (such as white phosphorus and red phosphorus on copper sheet) or design new verification schemes. For example, the following comparative experiments can be designed:  Experiment A (verifying combustible material): simultaneously heat small wooden sticks and a small piece of stone on copper sheet.  Experiment B (verifying oxygen): light two candles of equal length, one exposed to air, another covered with a beaker.  Experiment C (verifying ignition point): place small pieces of ping-pong ball and filter paper on copper sheet, heat evenly from one end of the copper sheet, observe the sequence of combustion. |
| Activity three:  extension experiment—application of fire extinguishing principles | Students use simple materials (candles, plates, water, sand, beakers, carbon dioxide generators, etc.) to design small experiments to simulate and verify the three major principles of fire extinguishing: removing combustible materials, isolating air (oxygen), lowering temperature below ignition point. |

**6.4.3 Stage three**

Stage three is outcome design and work creation. Each group, based on the inquiry results from stage two and combined with their group’s strengths, finally determines the presentation format and content framework of their kitchen fire safety guide. Students collaborate in divisions of labor, conducting creative activities such as copywriting, graphic design, video shooting and editing, model making, etc. Each group displays semi-finished products through gallery tours and other methods for inter-group peer evaluation. Based on feedback from classmates and teachers, final modifications and improvements are made to the works.

**6.4.4 Stage four**

Stage four is outcome presentation and multiple evaluation, including two activities, as detailed in Table 4:

**Table 4 Stage four activities**

|  |  |
| --- | --- |
| **Activity No.** | **Activity content** |
| Activity one:  community safety science exhibition and project outcome presentation | Simulate community publicity activities, with each group setting up exhibition booths to display and explain their works to community residents (played by students from other classes or teachers).  Each group conducts a 5-minute formal presentation, explaining the design concept, scientific basis, and innovative points of their work. |
| Activity two:  comprehensive evaluation and project summary | Based on each group’s presentations and works, conduct teacher-student mutual evaluation and student-student mutual evaluation. Teachers guide students to review the entire project process, summarize gains and shortcomings, and commend outstanding groups and individuals to reinforce students’ sense of achievement. |

**6.5 Project Evaluation Scheme Design**

To ensure comprehensiveness and guidance in evaluation, this project-based assignment adopts a multiple evaluation system combining formative and summative assessment, qualitative and quantitative approaches.

We designed the core competency four-dimensional assessment scale as shown in Table 5 below, used for comprehensive evaluation of students’ performance during the project process and final outcomes. This scale design references multi-dimensional assessment models and four-dimensional evaluation system concepts.

**Table 5 Unveiling the secrets of combustion” project core competency four-dimensional assessment scale**

|  |  |  |  |
| --- | --- | --- | --- |
| **Level A (excellent)** | **Level B (good)** | **Level C (satisfactory)** | **Level D (needs improvement)** |
| **Evaluation dimension 1. Scientific inquiry and practice (30%)** | | | |
| Can independently design and optimize comparative experimental schemes; operates standardly with detailed data recording; can provide reasonable explanations for abnormal phenomena; can skillfully complete escape drills. | Can complete experimental design under guidance; operates basically standardly and can record key data; can describe experimental phenomena; can smoothly complete escape drills. | Can participate in experimental design discussions; can complete experimental operations step by step; can record main phenomena; basically masters escape essentials. | Low experimental participation; non-standard operations; incomplete records; panicked performance in escape drills. |
| **Evaluation dimension 2. Knowledge integration and application (30%)** | | | |
| Deeply understands combustion and fire extinguishing principles and can creatively apply them in works; works are highly scientific, logically rigorous, and can solve complex situational problems. | Accurately understands combustion and fire extinguishing principles and can reflect them well in works; works have good scientific quality and comprehensive content. | Basically masters core principles of combustion and fire extinguishing; works can reflect main knowledge points but lack depth and breadth. | Understanding of combustion and fire extinguishing principles has deviations; works have obvious scientific errors. |
| **Evaluation dimension 3. Collaboration, communication and expression (20%)** | | | |
| Actively assumes core roles in the team, effectively organizes and coordinates; can clearly, fluently, and inspiringly present outcomes; works have novel forms and vivid expression. | Can actively participate in team cooperation and discussion, effectively complete assigned tasks; presentation is clear; works have relatively creative forms. | Can complete tasks assigned by the team but with average initiative; presentation is basically complete; works have conventional forms. | Poor team collaboration; unwilling or poor at expressing viewpoints; works are rough with unclear expression. |
| **Evaluation dimension 4. Social responsibility and innovation awareness (20%)** | | | |
| Shows extremely strong safety awareness and social responsibility; works are highly creative and practical, fully considering target audience needs; can propose unique insights or solutions. | Has good safety awareness and social responsibility; works have certain creativity and practicality; can make improvements on existing foundations. | Has basic safety awareness; works lack obvious creativity with average practicality. | Weak safety awareness; works are simple imitations without personal thinking or innovation. |

**6.6 Case Reflection**

The main advantages of this “unveiling the secrets of combustion—home kitchen fire safety action” project-based assignment case lie in: integrating abstract chemical knowledge, physical phenomena, experimental inquiry skills with life safety education, breaking down subject barriers; driving questions originate from life, with final outcomes serving the community, giving the learning process clear realistic significance and social value; through a series of carefully designed activities, students’ core competencies such as scientific inquiry, innovative thinking, and social responsibility are effectively exercised and enhanced in practice.

Challenges that may be faced in implementation mainly include: combustion experiments and escape drills pose certain safety risks, placing high demands on teachers’ safety management capabilities and schools’ hardware facilities; project-based assignments require diversified teaching resources (such as experimental equipment, multimedia devices, smoke generators, etc.), requiring school-level support; formative assessment places high demands on teachers’ observation, recording, and analysis capabilities, requiring teachers to transform their roles to become learning facilitators and promoters.

This project-based assignment can be further expanded, for example, combining with physics to explore energy conversion efficiency in combustion processes and design energy-efficient stoves; combining with information technology to learn programming or professional software for creating more interactive popular science works; even organizing students to visit community fire stations for field interviews and learning, extending the field of project-based learning from classrooms to broader social spaces.

**6.7 Case Transfer to Test Questions**

We can also modify and transfer this project-based assignment to test questions. The project-based test question design is as follows:

After completing the study of combustion and fire extinguishing, ninth-grade interest group students at the school conducted project-based learning with the theme “exploring combustion conditions”.

[Task one] Understanding combustion and explosion

(1) Among the following icons, those related to combustion and explosion are \_\_\_\_\_\_ (fill in letters).

A． B． C． D．

**Fig 1.** **Exploring Combustion Icons**

(2) The reactions that occur when red phosphorus, charcoal, and sulfur powder burn belong to \_\_\_\_\_\_\_\_\_\_\_\_ reactions among basic reaction types.

[Task two] Exploring combustion conditions and fire extinguishing

Interest group students conducted experimental inquiry using the well-sealed apparatus shown in the figure.

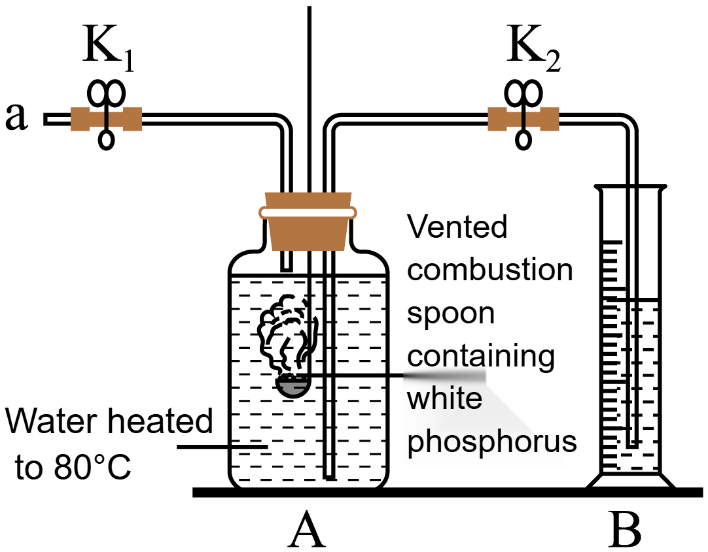


Fig 2. **Well-Sealed Apparatus**

Step I: Use glass rods to dip 95% alcohol and distilled water respectively and place them over flames, observe phenomena.

Step II: Insert a perforated combustion spoon containing white phosphorus into bottle A (empty bottle), observe that white phosphorus does not burn.

Step III: Fill bottle A with 80°C hot water, tighten the stopper, observe that white phosphorus does not burn.

Step IV: Open K1 and K2, blow air into bottle A through opening a, when the liquid level in the bottle is below the bottom of the combustion spoon. Close K1 and K2, at this time the volume of water entering measuring cylinder B is 200mL, observe that white phosphorus in bottle A burns.

[Experimental analysis and conclusions]

(3) ① In Step I, \_\_\_\_\_\_\_\_\_\_\_\_ is observed, indicating that alcohol is combustible while water is not.

② Comparing phenomena in Steps II and IV shows that one condition for combustible material burning is \_\_\_\_\_\_\_\_\_\_\_\_.

③ Comparing phenomena in Steps III and IV shows that one condition for combustible material burning is \_\_\_\_\_\_\_\_\_\_\_\_.

[Experimental reflection]

(4) In the experiment, if the alcohol lamp is accidentally knocked over and alcohol burns on the desktop, the fire extinguishing method is \_\_\_\_\_\_\_\_\_\_\_\_.

[Experimental Extension]

(5) In Step IV, after the apparatus cools for a period, open K2, if \_\_\_\_\_\_\_\_\_\_\_\_ is observed, it indicates that oxygen in air occupies approximately \_\_\_\_\_\_\_\_\_\_\_\_ by volume. If the experiment measures that the volume fraction of oxygen in air is less than expected, a possible reason is \_\_\_\_\_\_\_\_\_\_\_\_ (fill in one).

[Task three] Exploring whether remaining gas in gas collection bottle contains oxygen after white phosphorus combustion extinguishes

Interest group students used oxygen sensors to measure the volume fraction of oxygen when white phosphorus burns in a gas collection bottle, as shown in the figure.

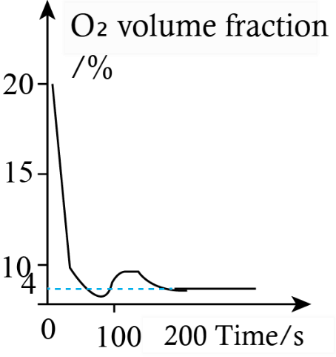


Fig 3. **volume fraction of oxygen**

(6) Through data analysis, your new understanding about combustion requiring oxygen is \_\_\_\_\_\_\_\_\_\_\_\_.

7. Conclusions

This study, through systematic exploration of the application of project-based assignments in junior high school science teaching, draws the following main conclusions:

(1) Educational value of project-based assignments

Project-based assignments, centered on driving questions and combining scientific knowledge with practical applications through inquiry activities in authentic contexts, can significantly enhance students’ scientific inquiry abilities, innovative thinking, and interdisciplinary comprehensive capabilities. Their “learning by doing” philosophy highly aligns with the core competency requirements of the “compulsory education science curriculum standards (2022 edition)”, providing an effective pathway for science education to move from knowing to doing.

(2) Principles and strategies for project-based assignment design

Successful project-based assignment design needs to follow principles of inspiration, comprehensiveness, authenticity, student agency, assessability, and clear objectives. Through strategies such as driving question guidance, task chain decomposition, interdisciplinary integration, tiered design, and diversified evaluation, teachers can effectively address challenges such as student ability differences, resource scarcity, and evaluation difficulties, ensuring maximum educational value of project-based assignments.

(3) Case analysis of junior high school science project-based assignments

Using “unveiling the secrets of combustion—home kitchen fire safety action” as a case study, this research demonstrates how project-based assignments cultivate students’ scientific literacy and social responsibility through the combination of scientific inquiry and social practice. This case validates the feasibility of the above project-based assignment design principles and strategies.

(4) Future research and practice directions

Although project-based assignments have shown significant advantages in junior high school science teaching, their implementation still faces limitations in terms of time, resources, and teacher capabilities. Future research should further explore how to optimize the implementation effectiveness of project-based assignments through technology empowerment, social resource integration, and teacher professional development support. Additionally, research should be strengthened on the adaptability of project-based assignments across different subjects and educational stages, promoting their application in broader educational contexts.

Project-based assignments, as a promising assignment teaching method, are still in a process of continuous development and improvement in their application and research in educational practice. It is hoped that future research will bring more innovation and breakthroughs to this field.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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