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# The Application of AI-Powered Project-Based Learning in Junior High School Biology---Taking "The Secrets of Angiosperm Growth" as an Example

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**Abstract:** In the contemporary era of rapid technological advancement, artificial intelligence (AI) has emerged as a transformative force within the global education system. Consequently, AI-enabled project-based learning (PBL) has become a critical requirement for modernizing pedagogical frameworks and fostering sustainable social development. This article presents a comprehensive case study focusing on "The Secrets of Angiosperm Growth," a foundational module from the seventh-grade lower-semester biology textbook published by the People's Education Press. The study systematically explores the integration of AI tools into the biology curriculum across four essential dimensions: the cultivation of fundamental life concepts, the enhancement of rigorous scientific thinking, the facilitation of inquiry-based practical skills, and the development of student attitude and social responsibility. By utilizing AI-enabled project-based learning methodologies, educators can create highly interactive and personalized learning environments that significantly boost student engagement and knowledge retention. The research demonstrates how AI applications, such as intelligent tutoring systems and virtual simulations, can effectively guide students through complex biological processes like angiosperm reproduction and development. Ultimately, this pedagogical approach aims to comprehensively develop students' core competencies in the sciences. The findings provide a robust, practical reference for junior high school biology teaching, offering actionable strategies for educators. Furthermore, this study promotes the effective implementation of the subject's broader educational function, ensuring that students are adequately prepared for future scientific endeavors in an increasingly digital and AI-driven world.

**Keywords:** artificial intelligence; project-based learning; biology education; core competencies; teaching strategies

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## 1. Introduction

Driven by the rapid advancements in artificial intelligence (AI), the integration of AI technologies into education has introduced both significant opportunities and complex challenges. The transformation of educational systems in the intelligent era necessitates a comprehensive approach to harmonize AI with innovative teaching methodologies [1, 2]. Among these methodologies, project-based learning stands out as a pivotal strategy for fostering students' inquiry-based thinking, enhancing their capacity for deep learning, and cultivating intelligent literacy [3–5]. This teaching approach, which emphasizes active exploration and problem-solving, must evolve to align with the dynamic trends of the intelligent era. By leveraging the capabilities of AI, educators can unlock new dimensions of teaching innovation and practice, thereby enriching the learning experience for students.

The application of AI in project-based learning offers a multitude of possibilities. AI can be utilized to personalize learning experiences, analyze student performance data, and provide real-time feedback, thereby enabling a more tailored and effective educational process. For instance, AI-driven tools can assist in identifying individual learning gaps and recommending targeted interventions, ensuring that each student receives the support they need to succeed. Additionally, AI can facilitate collaborative learning by enabling virtual environments where students can work together on projects, regardless of their physical location. These environments can simulate real-world scenarios, allowing students to apply theoretical knowledge to practical problems in a controlled setting.

To illustrate the potential of AI in project-based learning, consider the chapter "Growth of Angiosperms" from the junior high school biology textbook published by the People's Education Press. This chapter provides an excellent framework for integrating AI into the project implementation process. By employing AI tools, educators can design interactive and engaging activities that deepen students' understanding of the subject matter. For example, AI-powered simulations can model the growth processes of angiosperms, enabling students to visualize and manipulate variables such as light, water, and nutrients to observe their effects on plant development. Such interactive tools not only enhance comprehension but also encourage critical thinking and experimentation.

Furthermore, AI can streamline the project design process by automating routine tasks, such as data collection and analysis. This allows educators to focus on more creative aspects of teaching, such as developing innovative project themes and guiding students through complex problem-solving activities. AI can also support the assessment process by providing detailed analytics on student performance, helping educators identify areas for improvement and adjust their teaching strategies accordingly. By integrating AI into every stage of project-based learning, from planning to execution and evaluation, educators can create a more dynamic and effective learning environment that prepares students for the challenges of the intelligent era.

## 2. Incorporating Elements of Life to Establish the Project Theme

When selecting topics for project-based learning, it is necessary to follow the principles of disciplinary relevance, practical significance, and appropriate cognitive challenge, while maintaining a high degree of consistency with the requirements of focusing on major concepts and aligning with the cognitive characteristics of junior high school students in the Compulsory Education Biology Curriculum Standards (2022 Edition). In this context, the theme "The Secrets of Angiosperm Growth" is highly suitable because it integrates core textbook content on seed germination, plant growth, and flowering into a coherent learning sequence that is both scientifically meaningful and closely connected to students' everyday experience. Rather than presenting these topics as isolated knowledge points, the project organizes teaching around the connotation and extension of the important concept that the life cycle of green flowering plants includes stages such as seed germination, growth, flowering, fruiting, and death. This conceptual organization helps students understand that plant life activities are continuous, ordered, and regulated by both internal biological characteristics and external environmental conditions. It also supports the transition from fragmented factual learning to structured conceptual understanding, which is a central goal of biology education at the compulsory stage. From the perspective of curriculum implementation, this theme has several clear advantages. First, angiosperms are common in agricultural production, campus greening, home gardening, and natural surroundings, so students can easily observe real specimens and collect first-hand evidence. Second, the growth process of angiosperms is dynamic and visible, making it especially appropriate for long-term observation, experimental inquiry, recording, comparison, and explanation [6]. Third, the topic naturally supports interdisciplinary integration with mathematics, labor education, and practical activities, such as measuring plant height, counting germination rates, comparing light and water conditions, and analyzing changes over time. Through these activities, students can gradually establish scientific habits of observation, evidence-based reasoning, and reflective expression. The concepts that need to be formed for this theme are shown in

Table 1. Table 1 not only reflects the internal conceptual relationships among seed structure, germination conditions, vegetative growth, reproductive development, and life cycle completion, but also provides a basis for designing project tasks with clear progression and logical coherence. In actual teaching, students may begin by asking why some seeds germinate quickly while others do not, then extend their inquiry to how roots, stems, and leaves develop, and finally explore the conditions under which flowering and fruiting occur. Such a progression is consistent with students' cognitive development because it moves from concrete phenomena to abstract explanation, from direct observation to conceptual generalization, and from single-factor thinking to a more comprehensive understanding of biological systems. Therefore, this project is closely related to life, fully reflects the life elements of organisms, and has strong educational value, scientific rigor, and practical operability, making it highly suitable for project-based learning in junior high school biology.

**Table 1.** Conceptual Relationships of "the Growth Secrets of Angiosperms"

| Theme Content | Important concepts | Secondary concept |
|---|---|---|
| The secrets of angiosperm growth | The life cycle of green flowering plants includes stages such as seed germination, growth, flowering, fruiting, and death. | Seed germination requires sufficient air, suitable temperature, and adequate water. Root growth mainly involves cell division in the root apical meristem and cell growth in the elongation zone. Water is transported upwards through the xylem vessels in plant roots for the plant's use; most of the water is lost through transpiration.<br><br>Leaf buds develop into stems and leaves through cell division and differentiation. The most important structures in a flower are the stamen and the pistil. |

**3. Clarify the Curriculum Standards and Set Project Goals**

The project theme, "The Secrets of Angiosperm Growth," serves as a foundation for aligning the objectives with the curriculum standards. By integrating textbook content and focusing on core competencies, the project aims to foster a comprehensive understanding of plant biology. This approach ensures that students not only grasp theoretical knowledge but also develop practical skills and critical thinking abilities. The objectives are designed to bridge the gap between academic learning and real-world applications, emphasizing the importance of scientific inquiry and ecological awareness. By setting clear goals, the project provides a structured framework for students to explore the intricate processes of angiosperm growth while cultivating a deeper appreciation for plant life and its role in the ecosystem [7].

Cracking the code of life involves designing and conducting controlled experiments to investigate the conditions necessary for seed germination. This process allows students to explore the fundamental biological principles that govern the early stages of angiosperm development. By incorporating AI tools, students can predict growth patterns and compare these predictions with empirical data, fostering a deeper understanding of experimental design and data analysis. This hands-on approach not only enhances their ability to identify and address experimental errors but also strengthens their scientific reasoning and problem-solving skills. Through this activity, students gain insights into the complexities of life processes, laying a strong foundation for advanced studies in plant biology and related fields.

Deconstructing plant factories provides an opportunity for students to delve into the structural and functional aspects of plant physiology. By creating detailed models of root tips and leaves, students can visualize and understand the intricate processes of material transport within stems. The integration of AI simulations further enriches this learning experience by offering a dynamic representation of internal physiological activities, such as nutrient and water movement. This collaborative exploration encourages students to exchange ideas on optimizing plant cultivation techniques, fostering innovation and critical thinking. By emphasizing the compatibility of structure and function, this activity underscores the interconnectedness of biological systems, preparing students for future challenges in agricultural science and biotechnology [8].

Conveying ecological concepts involves a multifaceted approach to understanding and promoting the life cycle of angiosperms. By dissecting flowers, students can observe the intricate processes leading to fruit formation, gaining a hands-on appreciation for plant reproduction. AI tools are employed to simulate and deduce these processes, enabling students to identify and summarize the scientific principles underlying the life cycle of flowering plants. Beyond the classroom, students are encouraged to share their findings with local communities or schools, fostering a culture of green development and ecological awareness. This dissemination of knowledge not only reinforces their understanding but also instills a sense of social responsibility and respect for life. By engaging in these activities, students contribute to the broader goal of promoting sustainable practices and healthy living, aligning their academic pursuits with societal needs [9].

Through the integration of AI-enabled project-based learning, students are provided with a unique opportunity to explore the growth logic of angiosperms in a scientifically rigorous manner. This approach allows them to connect theoretical knowledge with practical applications, enriching their understanding of plant cultivation and ecological principles. By engaging in activities such as seed germination experiments, physiological modeling, and ecological dissemination, students develop a holistic perspective on the life cycle of green flowering plants. This includes key stages such as seed germination, growth, flowering, fruiting, and eventual senescence. The project not only enhances their academic and practical skills but also fosters a lifelong appreciation for the importance of green development and sustainable living. Ultimately, this comprehensive learning experience equips students with the tools and mindset needed to address future challenges in environmental science and agriculture.

## 4. Identify Driving Issues and Break Down Project Tasks

The three core elements of project-based learning revolve around its foundation in biological content, its application to solving real-life problems, and its ability to enable students to construct their own knowledge systems during the problem-solving process. The project learning plan titled "The Secret of Angiosperm Growth" serves as an exemplary model for integrating these elements. As illustrated in Figure 1, the driving question for this project is, "Can we become class farmers to provide a unique ingredient for the class food festival and summarize the ultimate secret of plants growing fast and well?" This question not only engages students in a practical and creative endeavor but also encourages them to explore scientific principles in depth.

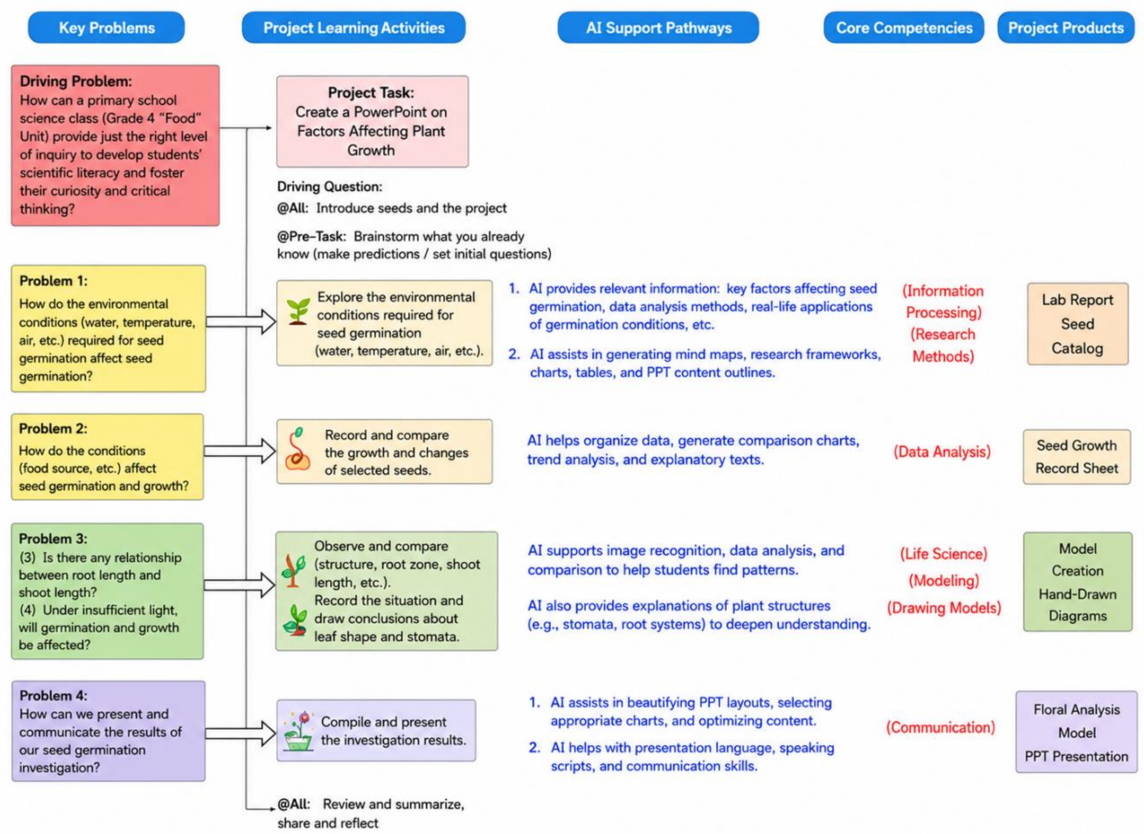


**Figure 1.** Project-based Learning Scheme for "the Growth Secrets of Angiosperms"

To achieve the objectives of the project, several sub-projects are designed to address specific questions. For instance, students are tasked with conducting controlled experiments to determine the optimal temperature and humidity conditions for plant seed germination. This involves setting up multiple experimental groups with varying environmental parameters and meticulously recording the germination rates to identify the most favorable conditions. Additionally, under the time constraints imposed by the food festival, students must evaluate different types of seeds to select those that germinate quickly while aligning with the class's culinary preferences. This requires a comparative analysis of seed types, considering factors such as germination speed, taste, and compatibility with the planned dishes.

Another critical aspect of the project involves investigating the relationship between weak plant growth and root absorption. Students are encouraged to hypothesize potential causes of poor growth, such as nutrient deficiencies or inadequate water uptake, and design experiments to test these hypotheses. By analyzing root structures and absorption rates, they can propose solutions to enhance plant health. Furthermore, the project addresses the challenge of managing environmental conditions during periods of intense sunlight. Students explore strategies to prevent stomatal closure, which can hinder photosynthesis and overall plant growth. This may include designing shading systems or optimizing irrigation schedules to maintain favorable conditions for the plants.

The project also delves into the developmental stages of angiosperms, particularly focusing on the ovary's growth and maturation. Students learn to identify key indicators of fruit development and determine the optimal harvest time to ensure the best taste and quality [4, 10]. This involves monitoring changes in fruit size, color, and texture, as well as understanding the biochemical processes that contribute to flavor enhancement. By synthesizing their findings, students can summarize the "ultimate secret" of promoting rapid and healthy plant growth, thereby addressing the driving question of the project.

Overall, this project-based learning approach not only fosters scientific inquiry and critical thinking but also provides students with practical skills and knowledge applicable to real-world agricultural practices. Figure 1 visually represents the structured framework of the project, highlighting the interconnectedness of its various components and the comprehensive learning experience it offers.

**5. Implement the Project Plan and Produce Project Results**

After the project was launched, students began implementing the tasks in accordance with the project requirements. During this phase, numerous challenges emerged due to the students' limited practical experience. To address these issues, teachers formed online groups to provide supervision and guidance. For instance, group members conducted research on relevant materials and utilized AI tools to draft experimental designs. Once the teacher reviewed and confirmed the feasibility of these designs, students proceeded with the planting phase. The experimental results, as depicted in Figure 2, demonstrated the outcomes of their efforts. Following the "awakening" of the seeds, students observed the healthy seeds and meticulously recorded the growth of seedlings. With the assistance of AI, they selected seeds exhibiting high vitality for further experimentation.

**Figure 2.** Results of an Experiment Investigating the Effect of Water on Mung Bean Seed Germination

When constructing root tip models, students opted to use pen tubes as substitutes for vascular bundles. This choice provided a vivid analogy while ensuring the materials were easily accessible. The "Colorful Flowers" and "Spinach Blowing Bubbles" experiments offered visually engaging demonstrations of water absorption, transport, and loss in plants. In the "Colorful Flowers" experiment, plants with stems were soaked in colored ink overnight, as illustrated in Figure 3. By cutting the stem with scissors, students could observe transverse or longitudinal sections, where the stained areas highlighted the vascular tissue. This hands-on activity allowed students to directly visualize the internal structures responsible for water transport.

**Figure 3.** Results of the "Colorful Flowers" Experiment

The "Spinach Blowing Bubbles" experiment, shown in Figure 4, provided a direct observation of stomata and their role in gas exchange. To conduct this experiment, two-thirds of a container was filled with water, and small holes were carefully made in spinach leaves using scissors. The spinach was then fully submerged in the water. By gently blowing air onto the spinach stem, students observed the formation of bubbles on the plant's surface. They accurately recorded the primary locations where bubbles emerged, thereby verifying the main sites of gas exchange in the plant. This experiment also encouraged critical thinking by posing the question: Why are bubbles predominantly distributed on the lower epidermis rather than the upper epidermis? This inquiry prompted students to delve deeper into the structural and functional differences between the two surfaces of the leaf.

**Figure 4.** "Spinach Blowing Bubbles" Experiment

Additionally, when dissecting flowers, students employed AI tools to observe the intricate structures of the flowers. By uploading real photographs of the ovary, the AI generated comparison images that illustrated the developmental process from flower to fruit. This visual representation provided a comprehensive understanding of how the ovary transforms into fruit, enhancing the students' grasp of angiosperm reproduction and growth processes.

After completing the aforementioned project tasks, students engaged in summarizing and concluding their findings, culminating in the creation of the final project deliverables [11, 12]. These included an experimental report, a seedling growth record sheet, model results, and an angiosperm growth manual [13, 14]. Throughout this process, students not only refined their teamwork and communication skills but also cultivated innovative thinking and a heightened sense of social responsibility [12]. By participating in these activities, they achieved the educational goal of "reduced quantity without reduced quality," ensuring that the teaching outcomes remained robust despite potential constraints [6, 14].

The project also played a pivotal role in fostering a scientific perspective on life among the students [14]. By engaging in hands-on experiments and utilizing advanced tools such as AI, they were able to bridge theoretical knowledge with practical application [14]. For instance, the seedling growth record sheet required students to meticulously document the growth stages of the plants, encouraging attention to detail and systematic observation [10]. Similarly, the experimental report demanded critical analysis and synthesis of data, further enhancing their academic rigor [4, 6].

Moreover, the creation of the angiosperm growth manual served as a comprehensive resource that consolidated their learning [4]. This manual not only documented the experimental procedures and results but also provided insights into the broader implications of plant growth and development [10, 11]. By integrating AI-generated visualizations and real-world observations, the manual became a valuable tool for understanding complex biological processes [9].

In addition to academic benefits, the project emphasized the importance of collaboration and adaptability [10]. Students learned to navigate challenges, such as unexpected experimental outcomes or logistical issues, by working together and seeking guidance from their teachers [11]. This collaborative approach not only improved their problem-solving skills but also instilled a sense of resilience and perseverance [5]. Furthermore, the use of AI tools introduced them to cutting-edge technologies, preparing them for future academic and professional endeavors [5, 14].

Ultimately, the project succeeded in achieving its multifaceted objectives [5]. It provided students with a holistic learning experience that combined theoretical knowledge, practical skills, and technological innovation [7, 13]. By fostering a scientific mindset and encouraging active participation, the project laid a strong foundation for their future academic and personal growth [1].

## 6. Design Project Evaluation, Evaluate Project Outcomes

The evaluation subjects, content, and methods of project-based learning should be diversified to ensure a comprehensive and balanced assessment of student performance. The evaluation subjects include peer evaluation, teacher evaluation, and group self-reflection, with each contributing to the overall assessment in a weighted manner: peer evaluation accounts for 30%, teacher evaluation constitutes 50%, and group self-reflection makes up the remaining 20%. This distribution ensures that multiple perspectives are considered, fostering a holistic understanding of individual and group contributions. The evaluation content is designed to cover a wide range of competencies and skills, including experimental design, data recording and analysis, model making, and work presentation. These components are critical for assessing both the theoretical understanding and practical application of knowledge. The evaluation methods integrate process evaluation and performance evaluation to provide a balanced approach. Process evaluation focuses on the ongoing efforts and strategies employed by students during the project, while performance evaluation assesses the final outcomes and deliverables. Specific methods used include written tests to evaluate theoretical knowledge, oral tests to assess communication and presentation skills, and activity reports to document the progression and outcomes of the project. To ensure consistency and objectivity in the evaluation process, an overall evaluation rubric for the project was developed. This rubric was informed by an in-depth analysis of the new curriculum standards, textbooks, and student learning outcomes. The rubric provides clear criteria and benchmarks for assessing various aspects of the project, ensuring that all participants are evaluated fairly and transparently. For instance, Table 2 outlines the evaluation rubric for the project titled "The Growth Secrets of Angiosperms," which serves as a detailed guide for assessing the specific tasks and objectives associated with this project. By employing such a structured and multifaceted evaluation framework, educators can better identify areas of strength and opportunities for improvement, ultimately enhancing the overall effectiveness of project-based learning. Furthermore, this approach encourages students to engage in self-reflection and peer feedback, fostering a collaborative and growth-oriented learning environment. Future research could explore the long-term impact of such evaluation methods on student learning outcomes and their applicability across different educational contexts and disciplines.

**Table 2.** Evaluation Rubric for "the Growth Secrets of Angiosperms"

| core competencies | Evaluation content | Evaluation criteria | Evaluation Details |
|---|---|---|---|
| Scientific thinking Inquiry Practice | Experimental Design | Scientific Logic Innovation | The process is scientifically innovative and easy to operate and implement.(5points ) Designed using conventional science, but difficult to implement.(3-4points) |

| | | | |
|---|---|---|---|
| | | | There are points to explore, but the process is flawed.(1-2points) |
| Scientific thinking Inquiry Practice | Data recording and analysis | Rigor Realism Exploratory | The data is objective and complete, and the analysis is dialectical and insightful.(5points) The data is complete, but the analysis is superficial.(3-4points) Incomplete records or incorrect analysis(1-2points) |
| Concept of life Scientific thinking | Model making | Artistry Innovation Scientific | The design is accurate, the materials are new, the proportions are scientific, and the aesthetics are unique.(5points) The proportions of the text and images are scientific, and the colors of the materials are appropriate.(3-4points) The illustration is out of proportion and uses only one color.(1-2points) |
| Concept of life Attitude and responsibility | Works Showcase | Infectious Richness Integrity | The presentation was engaging, rich in materials (covering all stages of plant growth), and the PowerPoint slides |

| | |
|---|---|
| | were visually appealing.(5points) |
| | The explanation was fluent, the content was comprehensive, and the visuals were harmonious. (3-4points) |
| | The presentation was rushed, incoherent, incomplete, and the PowerPoint slides were poorly designed.(1-2points) |

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