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Balancing Tradition with Innovation: Reform and Practice of Genetics Experiments for International Students in the Aeronautics and Astronautics and Civil Aviation

Yuan GAO
College of Life, Northwestern Polytechnical University, Xi'an Shaanxi, 710129, China

Abstract

Genetics experiments are an integral part of the core curriculum for undergraduate students in the life sciences, and are essential for cultivating innovative talent in line with the evolving demands of contemporary higher education. This research explores innovative reforms and practices in genetics education for international students against the backdrop of 'San Hang' (Aeronautics, Astronautics, and Civil Aviation). By combining traditional experiments with the latest advances in genetic research and technology, the study enhances the exploratory and practical dimensions of the experiments. The introduction of open-ended experimental design empowers students to independently identify problems, formulate hypotheses, and conduct experimental verification, thereby fostering their innovative thinking and practical skills. The results show that these reforms have improved the quality of teaching, refined the content of experiments, and established a distinctive 'San Hang'-oriented genetics teaching system that fosters a holistic set of innovative competencies in students.

Keywords Genetics Experiments, International Students, 'San Hang' Characteristics, Educational Reform, Teaching System

1 The Need for Reform in Genetics Education for International Students

The 20th National Congress of the Communist Party of China emphasized, "We must regard science and technology as our primary productive force, talent as our primary resource, and innovation as our primary driver of growth. We will fully implement the strategy for invigorating China through science and education, the workforce development strategy, and the innovation-driven development strategy. We will open up new areas and new arenas in development and steadily foster new growth drivers and new strengths." It also stresses "Improving systems for

scientific and technological innovation that will remain at the heart of China's modernization drive." Universities and colleges, as the primary bases for nurturing innovative talents, have a significant responsibility to cultivate the spirit of innovation among university students and to improve their innovative capabilities[1].

Northwestern Polytechnical University is committed to becoming a distinctive multidisciplinary, research-oriented, and open world-class university with Chinese characteristics, exerting significant influence in the fields of aeronautics, astronautics, and civil aviation ('San Hang'). The university's main disciplines of 'San Hang' are all national key disciplines, highlighting its prominent strengths and characteristics. Adhering to the 'San Hang' characteristics has become the primary guideline of its educational philosophy. In recent years, the university has continuously deepened the reform of innovation and entrepreneurship education, focusing on enhancing students' innovative spirit, entrepreneurial awareness, and capabilities in innovation and entrepreneurship, with the aim of cultivating high-quality, top-notch innovative talents[2].

Experiment teaching is a vital component of higher education, enabling students to identify and address problems through practical activities, thereby applying theoretical knowledge to real-world scenarios, which is essential for enhancing students' innovative and practical skills[3]. Genetics experiments are a crucial part of the curriculum for undergraduates in fields such as life sciences, medicine, and agriculture[4]. These courses typically encompass a range of genetic study areas, including classical, cellular, molecular, and population genetics, and feature a mix of verification, comprehensive, and exploratory experiments. Verification experiments continue to play a significant role in genetics education, allowing students to deepen their grasp of foundational theories, refine their experimental techniques, and make the critical transition from theoretical knowledge to practical application[5].

In the realm of genetics experiments, the fruit fly hybridization experiment stands out as a quintessential verification experiment, emphasized in teaching due to its comprehensive nature, intricate procedures, and the substantial cognitive challenge it presents. Traditional teaching methods, characterized by tedious steps and extended timelines, have often led to a lack of student engagement and suboptimal learning outcomes—an issue prevalent across numerous educational institutions[6]. To address this, some educators have introduced open-ended and design-based experiments into the fruit fly curriculum and other similar projects, achieving certain educational reform effects, but student interest still requires a boost[7]. The same challenges are observed in cytogenetics, particularly in experiments observing chromosome behavior. Consequently, there is an urgent need to innovate while preserving the essence of verification experiments, making them more engaging and fostering creativity.

Furthermore, in the instruction of genetics experiments for international students, there is a noted enthusiasm for exploratory experiments in molecular genetics. Concurrently, as other courses undergo reform, the demand for learning experimental techniques among students evolves[8]. To align with the evolving demands of higher education in China and to foster a spirit of innovation and practical skills among students, the imperative for reform in genetics experiment teaching is clear. With the goal of enhancing the impact of verification experiments and

nurturing students' innovative capabilities, this reform initiative leverages our institution's unique 'San Hang' characteristics to explore innovative and open concepts, content, and systems in genetics experiments. This approach aims to satisfy the demands of higher education development in the new era and to enrich the theoretical underpinnings of experimental teaching.

2 Challenges in Genetics Experiment Instruction for International Students

2.1 Diminished Student Interest in Verification Experiments and Subpar Teaching Effectiveness

Genetics experiments encompass a plethora of verification experiments, including the observation of fruit fly traits, hybridization studies, and the examination of chromosome behavior. Given that the outcomes of these experiments are predetermined, they fail to pique the interest of students. The fruit fly hybridization experiment, in particular, demands prolonged cultivation, necessitating substantial after-class time for fruit fly maintenance, which can lead to waning interest and patience among students. This diminishes their enthusiasm and engagement in laboratory sessions and consequently impacts the effectiveness of teaching. Furthermore, the primary objective of these verification experiments—to reinforce and solidify theoretical knowledge—does little to foster the development of students' practical skills and innovative capabilities.

2.2 Disconnection Between Genetics Experiment Curriculum and Institutional Identity

Genetics experiments are a staple in the Biotechnology curriculum across various institutions and typically encompass foundational experiments such as observing the life cycle of fruit flies and the behavior of chromosomes. These experiments prioritize the development of practical laboratory skills and the importance of communicating and discussing results, often through experimental reports, to enhance students' expression and communication abilities. For engineering colleges, genetics experiments should particularly highlight the practical application of these skills, providing students with insights into how genetic knowledge is applied in real-world production and research settings. Currently, the selection of experimental content and the teaching methodology do not sufficiently integrate with the unique 'Sanhang' context of our institution, nor do they align well with the developmental goals of the school and the college, or the objectives of professional training, thus failing to adequately foster the comprehensive qualities of students.

2.3 The Lagging Genetics Experiments Teaching Model

The reform of genetics experimental teaching is an ongoing and dynamic process. The traditional model, which is centered around the teacher and includes lectures, demonstrations, student participation, and result analysis, has increasingly revealed its limitations. This model, with its emphasis on the teacher's dominant role, overlooks the active involvement that students should

have in their education, thereby placing them in a passive learning state. It is particularly deficient in stimulating students' interest and in nurturing their capacity for innovation.

3 Strategies for the Reform of Genetics Experiment Teaching for International Students

The current educational reform is centered on enhancing the efficacy of verification-based experiments, with the goal of fostering students' innovative capabilities. It integrates the distinctive 'San Hang' academic strengths of our institution to explore innovative and open-ended genetic laboratory teaching philosophies, curricula, and systems. The reform is primarily realized through the following three dimensions:

3.1 Enhancing the Exploratory and Innovative Elements of Traditional Verification Experiments Within the 'San Hang' Framework to Stimulate Students' Learning Interest

Innovative experimental approaches preserve the essence of verification experiments, where the primary objective is to reinforce theoretical knowledge through practical application[9]. These methods, while maintaining the foundational aspects of verification, introduce an element of exploration and innovation that piques students' curiosity and fosters deeper engagement with the subject matter. Students not only solidify their theoretical understanding but also enhance their experimental techniques and cultivate a spirit of scientific inquiry and innovation. Integrating traditional verification experiments with the unique 'San Hang' framework of our institution amplifies the experiments' exploratory and open-ended nature, adding an enjoyable dimension to the learning experience. Teachers provide ample trust and positive reinforcement during the experiments, effectively motivating and empowering students to take an active role in their learning process.

3.2 Developing an Open Experimental Teaching Framework With 'San Hang' Characteristics to Cultivate Innovation

Focus on student-centered curriculum reform and pedagogical innovation, leveraging subject projects to drive the transformation of experimental teaching models[10,11]. Encourage students to engage in innovative practice activities to cultivate their scientific spirit, practical skills, and innovative awareness. Utilize the Life Sciences Innovation Practice Base for conducting open experiments, enhancing teaching quality, and further refining and integrating the curriculum content. Integrate this with "Sanhang" disciplinary knowledge to explore new experimental projects, thereby establishing an open experimental teaching system that reflects the distinctive features of 'San Hang'.

3.3 Refining the Experimental Techniques Curriculum to Align With Modern Genetics and Research Practices

In the ever-evolving landscape of biological sciences, the field of genetics continues to forge ahead with new concepts and breakthroughs. It is imperative to refine long-established experimental materials by preserving their core value while eliminating outdated aspects. We must honor the legacy of classical experiments while simultaneously infusing them with innovative approaches to transcend the obsolescence often associated with traditional experimental methods. This will result in an educational system that is fully integrated with cutting-edge genetic technologies and current scientific endeavors. By vigilantly monitoring the latest advancements in the discipline and skillfully incorporating this knowledge into our teaching practices, we can distill the quintessence of both domestic and international exemplary teaching resources. This ongoing process of curriculum renewal and reform ensures that our educational offerings remain contemporary yet rooted, scientifically rigorous, and comprehensively structured.

3.4 Enhancing Educational Quality and Outcomes Through Innovative Pedagogical Approaches

We advocate for the exploration and integration of cutting-edge pedagogical strategies, including virtual reality, blended learning, design thinking, and project-based learning, to significantly boost student participation and the overall quality of learning experiences. By leveraging open educational resources, we aim to foster an innovative and adaptive learning environment that is conducive to the evolution of genetic experiment instruction. This approach is designed to construct a comprehensive reform framework for genetic experiment teaching, thereby elevating both the quality and effectiveness of our educational endeavors.

4 Approaches for the Reform of Genetics Experiment Teaching for International Students

4.1 Fostering a Modern Experimental Teaching Philosophy to Cultivate Innovative Talents

In pursuit of the educational objectives of establishing a strong foundation, enhancing capabilities, celebrating individuality, and fostering innovation, it is imperative to adopt a contemporary perspective on experimental teaching. This involves shifting from a teacher-centered to a student-centered paradigm, where students are encouraged to take an active role in problem analysis and resolution. The emphasis is on igniting students' passion for learning and promoting their autonomy, thereby creating a synergistic relationship between knowledge dissemination and skill development. This approach is particularly aimed at strengthening students' practical skills and innovative thinking.

4.2 Enhancing Experimental Curriculum and Establishing an Innovative Framework

4.2.1 Streamline the Curriculum to Avoid Redundancy

Eliminate redundant and outdated experiments that are already covered in other courses, such as the "Observation of Chromosome Behavior in Plant Mitosis," which has been addressed in second-year cell biology classes. Refine the teaching of repetitive techniques like "DNA Extraction and Purification" and "PCR Amplification with Agarose Gel Electrophoresis," which are staples in molecular biology, by integrating them with innovative projects. This integration fosters a symbiotic relationship between teaching and research, expanding students' perspectives, and nurturing their innovative spirit.

4.2.2 Transform Verification Experiments Into an Engaging Open-Ended Model

Revamp traditional verification experiments by incorporating elements of 'San Hang' to enhance their appeal. Experiments that utilize the effects of microgravity and radiation on fruit fly traits not only deepen students' comprehension of the practical applications of 'San Hang' in genetics but also broaden the genetic variability available for study. Introducing exploratory elements into fruit fly hybridization experiments, by manipulating gravity and radiation, allows for a deeper investigation into the impact of spatial factors. This approach enriches the genetic analysis of fruit fly esterase isoenzymes. Make full use of the life sciences research and innovation facility to bolster the transformation of genetics experiments, ensuring they are open and adaptable to a broader academic community or research approach.

4.2.3 Cultivate Student Initiative Through an Innovative Experimental System

Innovative experiments are designed to foster students' creative thinking by moving away from rote learning and towards a more open-ended approach. Students are encouraged to autonomously design experiments within small groups of 2-3 members, merging 'San Hang' concepts with current hot topics in life sciences. Under the guidance of instructors, students research, discuss, and formulate experimental plans, culminating in the completion of an experimental report and an oral presentation. This methodology fully engages students, encouraging proactive learning and the development of a robust innovative experimental framework aimed at producing high-caliber, innovative individuals.

4.3 Enhancing Experimental Techniques to Align the Curriculum With Contemporary Genetic Technologies

The landscape of biological research is continuously transforming. It is essential to distill the essence of traditional experiments, leaving behind outdated practices and integrating innovative approaches. Despite the broad scope of molecular genetics, students often lack proficiency in software design and gene analysis. To address this, the curriculum should incorporate bioinformatics

analysis techniques, enabling students to not only acquire experimental skills but also develop the capability to independently design experiments.

4.4 Employing a Variety of Innovative Teaching Methods to Enhance Educational Outcomes

By embracing the concept of blended learning, we can seamlessly combine in-person instruction with online resources. The integration of virtual reality in science education can offer a deeply immersive experience, akin to virtual labs, which can significantly enrich learning. The promotion of blended learning that leverages open educational resources fosters an environment of innovation in both teaching and learning. Furthermore, project-based learning allows students to engage with and apply genetic concepts while tackling real-world challenges, thus stimulating their active involvement and fostering the growth of their innovative skills. The incorporation of a design thinking framework within project-based learning, accompanied by a concrete implementation example, motivates students to approach problem-solving with creativity.

5 Impact of the Reform in Genetics Experiment Teaching for International Students

5.1 Enhancing Traditional Verification Experiments With Exploration and Innovation Under 'San Hang' Features, Stimulating Students' Interest

The integration of 'San Hang' characteristics into the experimental teaching approach has skillfully infused a spirit of exploration and innovation into traditional verification experiments without altering their foundational nature. Students have not only confirmed theoretical principles through practical operations but also uncovered the inherent exploratory, open-ended, design-oriented, and hypothesis-driven aspects of scientific knowledge. This approach has significantly piqued students' curiosity, leading to a more engaged and proactive learning experience. The experiments have not only reinforced theoretical understanding but also honed experimental skills and fostered a spirit of innovation in scientific inquiry. By merging traditional experiments with 'San Hang' features, the learning process has become more exploratory and enjoyable, with students approaching their studies with questions and receiving ample trust and encouragement from teachers, thereby enhancing their motivation and autonomy.

5.2 Developing an Open Verification Experiment Teaching System With 'San Hang' Features to Cultivate Innovation

Continuous monitoring of the latest developments in the field, integrating cutting-edge scientific knowledge into the curriculum, and incorporating the best practices from advanced educational materials both domestically and internationally have led to a unified curriculum that is modern, foundational, scientific, and systematic. Through ongoing educational reforms, the teaching content has been refined and integrated, gradually improving the experimental teaching system.

By progressively integrating 'San Hang' knowledge with teaching content and actively exploring and developing new experimental projects, an open verification experiment teaching system with distinctive 'San Hang' features has been established. This system has effectively nurtured students' innovative consciousness and significantly boosted their innovative capabilities.

6 Conclusion

In the context of 'San Hang', we have conducted profound reforms and practical implementations in genetics experiments for international students, aiming to harmonize traditional strengths with innovative demands. While preserving classic experimental projects, we have incorporated the latest research findings and technologies in genetics to enhance the cutting-edge and exploratory aspects of the experiments. The introduction of open experimental designs has enabled students to identify problems, propose hypotheses, and validate them through hands-on experiments. This teaching model has not only solidified students' foundational knowledge and core skills but also cultivated their independent exploration and innovative thinking. With guidance and inspiration from teachers during the experimental process, students' interest and enthusiasm for learning have been ignited. Consequently, we have not only elevated the quality of teaching and refined the experimental content but also successfully established a genetics experiment teaching system characterized by 'San Hang', comprehensively developing students' innovative consciousness and abilities.

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Author Biographies

Yuan GAO, born in ShaanXi province in 1993, is an assistant researcher focusing on genetics research. Email:gaoyuan2021@nwpu.edu.cn, https://orcid.org/0009-0004-7949-0686.

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