ORIGINAL ARTICLE

Project-Based Learning in Chinese Middle-School Students Is More Effective than the Traditional Teaching Method: An Experimental Study

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Abstract: This study explores the teaching method of project-based learning (PBL) compared to the traditional teaching method in Chinese schools by investigating the effects of PBL on junior school students. A teaching unit lasting two weeks on inheritance and genetics was used as curriculum and student achievement compared between an experimental group (n = 107) where PBL instruction was used versus the control group (n = 103) where standard traditional classroom instruction was used. Students in the PBL group had significantly higher scores in learning procedure (d = 1.003), achievements (d = 0.566) and students' self-assessment (d = 1.539). The overall effect size for the PBL group was d = 0.989.

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Literature Review

PROJECT-based learning (PBL), honored as a 'most striking innovation,' holds great interest as a new teaching method (Li, 2010). The method is based on using real-life events for learning. In this learning process, teaching objectives are met by having students complete projects related to the curriculum in the context of real-life situations. The procedure in PBL is for students to: 1) collect information and initiate a project based on the questions provided by teacher or themselves; 2) establish a group, discuss possible projects and form a project plan; 3) execute the project; 4) present project results and conclusions (Li, 2018). Rather than being teacher-, class-, or textbook-centered, PBL is student-centered, relying on the initiative of students to learn. As students carry out projects, they integrate knowledge from numerous subjects and present visual results; this ensures their cooperation, problem-solving and critical thinking abilities are well-trained. Students gradually become skilled communicators and advanced problem-solvers (Li, 2010; Chen, 2017; Bell, 2010). In view of the unique advantages of PBL as a teaching tool in personnel training, local governments and schools in many countries have begun to embrace the use of PBL in a variety of courses. Existing studies indicate that development of PBL-related courses is beneficial to students' future education and career development (Ralph, 2015).

In recent years, some regions and schools in China have begun to explore PBL as a teaching method (Zhang, 2019; Song, 2019). However, Chinese teachers are constrained to teach according to an established teaching plan and content framework, unlike teachers in European and American countries that often have more flexibility to determine their own teaching method and content. This limits Chinese teachers' ability to implement PBL. Moreover, Chinese teachers are accustomed to traditional teaching methods and student-centered teaching concepts, which weaken the promotion and implementation of PBL in China. To date, few cases of PBL in Chinese classes exist and empirical research concerning curriculum design, operational process and evaluation of effects for PBL as a teaching method is especially lacking. Therefore, this study explored the curriculum design and procedures of PBL within the context of the environment and requirements of China's education system to assess the effect of PBL on students' learning procedure, achievements, and self-assessment. Lessons on genetics taught in junior high school were used as an example, with a focus on the teaching unit 'biology inheritance.'

Research Design

Participants

The study included 219 students in four classes in a junior high school in Huaian, Jiangsu Province. It is one of the best schools in Huaian with students in this region random-

ly allocated to this school. After questionnaires and classroom observations, 210 valid samples remained, including a control group (n = 103) where students received traditional teaching and an experimental group (n = 107) where students received PBL instruction. Students in four class received introduction from the same teacher, and the only difference between experimental and control group was difference in teaching method. Two classes participated in control group and the number of students is 50 and 53 separately. The number of two classes in experimental group is 52 and 55. Students' pre-experiment scores, family background, and gender ratio did differ significantly between groups, indicating that control and experimental groups were equivalent.

Research Method

Since no authoritative scale met the needs of this study, a questionnaire was designed specifically for this study. The questionnaire included 15 questions about students' learning effects and self-efficacy, including learning procedures, achievements in genetics, and students' self-assessment.

Learning procedure. This dimension explores students' learning methods under different teaching modes to ascertain whether PBL improves students' self-learning ability. Five questions were included: 1) I have investigated the genetic phenomena between my parents and myself; 2) I have learned the relationship among DNA, genes and chromosomes through many methods; 3) I have investigated the application of DNA in life; 4) I have carried out cooperative learning in this unit; and 5) I have carried out independent research in this unit.

Achievements in genetics. This dimension compares students' learning achievements under different teaching modes. Four questions were included: 1) I understand knowledge about genes, and chromosomes; 2) I understand the concept of traits and can give some examples to explain; 3) I can use pictures to express the relationship between DNA, genes and chromosomes; and 4) I can design a program to help lost children find their families.

Students' self-assessment. This dimension compares students' self-assessment under different teaching methods. Six questions were included: 1) I am interested in the learning content of this unit; 2) My cooperative ability has been exercised in this unit learning; 3) I learned how to better solve problems in the learning of this unit; 4) I liked the teaching methods of this unit; 5) My ability has been improved in the learning of this unit; and 6) I have gained a new understanding of biology curriculum in the learning of this unit.

Each question had five possible rating levels: agree strongly (5), agree (4), neither agree nor disagree (3), disagree (2), and disagree strongly (1). Thus, the higher the score, the more the better the student had learned. Cronbach's α and Kaiser-Meyer-Olkin are 0.923 and 0.926 for the whole questionnaire, 0.764 and 0.671 for the dimension of learning procedure, 0.739 and 0.752 for the dimension of achievements in genet-

ics, and 0.965 and 0.905 for the dimension of students' self-assessment; these values indicate good reliability and validity of the questionnaire.

Intervention

The whole experiment lasted two weeks. During this period, according to the prescribed teaching content, teachers used two teaching methods to implement teaching in the experimental group and the control group respectively.

Research focused on the teaching content of inheritance in organisms to improve students' abilities in: understanding of DNA as the main genetic material; describing the relationships between chromosomes, DNA and genes; and giving examples of characteristics controlled by genes. In the experimental group, students were taught using the PBL method, while in the control group, students received traditional instruction. Students participated in pre- and post-intervention tests, which included the three dimensions discussed above to make comparisons between groups.

PBL instruction. Based on the central theme of the project, students' activities mainly focused on helping abducted children find their families. Three critical tasks proceeded as follows. First, after a teachers' brief introduction, students learned on their own to gain a deep understanding of genetics. Second, students flexibly applied their knowledge about genetics learned before to design and optimize solutions to the task through several team discussions. Third, after the presentation of plans from different groups, the class agreed on a final feasible plan to help abducted children find their families.

Control instruction. Teachers clarified concepts of chromosomes, DNA and genes to the whole class. Students had few opportunities to discuss the relationship among these concepts and when doing so had to follow teachers' lead and provide responses to teachers' questions. Student achievements were assessed by the teacher.

Results

Class observation

Anecdotal observations suggested student learning under PBL differed substantially from traditional teaching methods. Experimental students had greater enthusiasm for learning and a greater willingness to communicate and cooperate with teachers and classmates. In PBL, the principle of student-centered learning reconstructs the student-teacher relationship such that teachers act as coordinators to establish a system of curriculum knowledge with students rather than as leaders or controllers in the teaching process. Students have more opportunities to explore activities and to learn by themselves in order to accomplish learning tasks. Therefore, students participated in more activities and completed learning tasks through peer-cooperation. In this study, the task

of 'Finding Their Families' was designed to meet the PBL teaching goal and it required increased student involvement in the learning process.

Control students received the traditional Chinese teaching method, namely, the mainstream teacher-led, textbook-based teaching method. The teaching process was successfully completed. However, teachers imparted knowledge and students could only passively accept it. In teacher-student communication, teachers raised questions and students had to answer. Observations of this teaching method suggested that many students were distracted and found it difficult to follow the teachers and accomplish the necessary learning process.

Student Achievements

Effect size data were calculated as pre- minus post-test data. **Table 1** summarizes changes in scores for learning procedure, achievements in genetics, and students' self-assessment for students in the experimental and control groups. In the pre-test, no significant differences were present in the three dimensions between experimental and control students, implying that both groups were equivalent before learning about the 'Inheritance of Organisms.' In post-test results, experimental students had higher test scores than did control students for all scales, indicating a positive effect of PBL.

Specifically, the overall effect size of using PBL over the traditional learning method was large at 0.989 (a big effect size), indicating an overall benefit for experimental students. For the learning procedure dimension, was a big effect size d = 1.003, implying PBL encourages students' independent learning and involves them in the learning process. Effect size for achievements in genetics was medium at d = 0.556, indicating experimental students had increased knowledge mastery. The largest effect size occurred in the dimension of students' self-assessment, with d = 1.539, which was a big effect size for improving students' learning acquisition.

Discussion and Conclusion

This research compared traditional teaching methods with PBL methods and showed that PBL is an effective teaching strategy. Existing studies indicate that PBL can improve students' abilities in inquiry, program-design and decision-making (Doppelt, 2005). PBL also improves students' vocabulary in computer and science lessons (Bilgin, et al. 2015). Other results have found that PBL teaching encourages student interest in hobbies and careers related to engineering and technology (Sari, Alici, & Sen, 2018). Further, researchers and decision-makers are more willing to provide career recommendations for these students (Miles, Slagter, & Mensah. 2015). Compared with traditional teaching methods, PBL increases students' academic performance, improves students' motivation to learn and cultivates students' critical thinking (Karacalli & Knrur, 2014; Rajan, Gopanna & Thomas, 2019). Consistent with previously published research, our

Table 1. Pre- and Post-Test Means, Standard Deviation, and Effect Size.

	Pre-test				Post-test				
	Control (N=103)		Treatment (N=107)		Control (N=103)		Treatment (N=107)		Effect Size
	M	SD	M	SD	M	SD	M	SD	d
Learning Procedure	2.282	0.874	2.815	0.499	2.559	1.581	4.579	0.444	1.003
Achievement in Genetics	3.305	0.882	3.417	0.814	3.993	1.187	4.614	0.448	0.556
Students' Feeling and Efficiency	1.319	0.422	1.216	0.243	3.277	1.465	4.623	0.511	1.539
All Dimensions	2.302	0.726	2.482	0.519	3.276	1.411	4.606	0.468	0.989

Control: the control group; Treatment: the treatment group; M: Mean; SD: Standard Deviation; d: Cohen's d

results suggest a positive impact on students' learning procedure, an improvement in their knowledge capacity and ability, and improved learning acquisition.

The small sample size, short experimental time and lack of random sampling by teaching level within schools of different regions limits the conclusions we can reach from this research. Nonetheless, as one of few empirical studies on PBL in mainland China, the research can provide a foundation for further research on, and use of, PBL in other regions.

Based on the results of this research, we are optimistic that PBL is relevant to China's curriculum design under current teaching conditions in China. Teachers are likely to worry about deterioration of students' scores when teaching via the PBL method, since good marks are considered a critical goal by teachers and schools. Results in this study should reduce teachers' concerns. PBL increased students' learning interest and improved their problem-solving abilities, cooperation and communication. Thus, PBL is an effective way for students to learn and deserves further exploration.

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