10.18686/neet.v2i3.4178

Effectiveness of Micro Project-Based Learning in Improving Academic Performance and Scientific Attitudes in Chemistry Education

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Abstract: The traditional methods of teaching chemistry are no longer sufficient for talent development in the 21st century. Although project-based learning can address this issue, time constraints often limit its effectiveness. This study introduces micro project-based learning (MPBL) as an educational intervention, aligning with PBL principles but requiring less time. The research explores the impact of MPBL on students' academic performance and scientific attitudes in high school chemistry. The experiment involved implementing MPBL in experimental group (n=35) and traditional method in control group (n=35), utilizing pre-test, post-test, and modified version TOSRA test for quantitative analysis, and a semi-structured interview for qualitative analysis. The results indicate that MPBL has a positive influence on academic performance and scientific attitudes, demonstrating its effectiveness in high school chemistry education.

Keywords: High School Chemistry Teaching; MPBL Method; Iodine Extraction from Kelp

1. Introduction

In the face of complex issues such as environmental pollution, energy depletion, and climate change, education plays a critical role in cultivating responsible and capable future citizens. Traditional high school chemistry education often relies on direct instructional approach that limits student engagement, resulting in a deficiency in their ability to apply learned knowledge to real-world challenges[1]. Various studies have shown that project-based learning (PBL) is a beneficial strategy in science classrooms to improve the quality of science education, empowering students to utilize their scientific expertise to tackle practical problems[2]. Specifically, PBL is a student-centered model that integrates collaborative learning, inquiry-based teaching, and independent exploration. By engaging in problem-solving in authentic settings, students construct and apply concepts through their final projects. Research in this field indicates that PBL not only enhances students' teamwork skills, attitudes, self-perception, and learning abilities within a cooperative learning context, but also contributes to improved academic performance, deepened conceptual understanding, heightened interest and curiosity, and a strengthened passion for learning[3],[4].

Several studies have identified the primary challenge of implementing PBL in real classrooms as a long time needed for the PBL cycle, which often conflicts with limited class time[5]. In response to this issue, a more manageable alternative approach—micro project-based learning (MPBL) has been proposed. MPBL has the same fundamental principles and mechanisms with PBL, but MPBL has a condensed learning cycle, easier design and implementation. It serves as a lighter version of PBL suitable for regular classroom settings[6],[7]. Studies found that the utilization of MPBL in high school chemistry classes to improve students' comprehension of sodium bicarbonate and essential learning skills, effectively addressing the compatibility challenges between PBL and the practicalities of high school teaching[8].

Kelp is rich in iodine elements, making it a valuable resource for iodine extraction. This process is commonly used as a practical example in high school chemistry to demonstrate oxidation-reduction reactions in industrial settings. The extraction of iodine from kelp involves key technical concepts such as substance separation, purification, recycling, environmental sustainability, and cost-efficiency. By engaging in this experiment, students can develop a foundational understanding of substance extraction methods. However, traditional laboratory experiments often limit students to following instructions without fostering problem-solving abilities. On the other hand, PBL cycles may not be feasible within the limited class hours of high school. Therefore, this study presents a micro-project focused on 'iodine extraction from kelp' for high school chemistry classrooms. This project, requiring only 3 class hours, offers students the opportunity to tackle real-world challenges and promotes active participation. The research aims to explore the influence of MPBL on students' academic performance and scientific attitudes.

The research questions are as follows:

(1) To what extent does the utilization of the MPBL teaching method improve students' academic performance?

(2) How does the MPBL teaching method influence students' scientific attitudes?

2. Research Methodology

2.1 Research Design

The study was conducted during the fall semester of the 2023/2024 academic year at a local public high school in China. A quasi-experimental research design was employed in this study, with the experimental group receiving MPBL teaching and the control group receiving traditional experimental teaching. A semi-structured interview was conducted after this project, selecting 8 students. Data analysis was conducted using both qualitative and quantitative methods.

2.2 Participants

The sampling method used in this study was purposive sampling, where two classes with the closest midterm exam scores were selected to participate in the research. Thirty-five students from the experimental group and thirty-five students from the control group were identified to participate in the study. Throughout the research process, both groups were taught by the same teacher, ensuring consistency and controlling for external factors.

2.3 MPBL Pedagogical Approach and Process

The students engaged in 'iodine extraction from kelp' micro-project within 3 class hours, with each class lasting 45 minutes. This project consisted of six stages, namely task design and introduction, implementation, presentation and review, evaluation, summary and reflection, feedback and adjustment[9]. In the initial stage of the project, the teacher provided a kelp food manual to the students. Students utilized internet resources to gather information on the method of iodine extraction from kelp. During the implementation stage, group members collaborated in experimental inquiry activities, investigating the principles and specific procedures of iodine extraction from kelp, including extraction, enrichment, and iodine content measurement. Through the process of experimental inquiry, students applied their learned knowledge concepts and critical thinking skills to the experimental activities, resolving practical issues encountered during the experiment. At the final stage of the project, students show their product and experiment results. They receive evaluations from both the teacher and other group members. Based on the feedback received, students continue to refine their experiments and produce a project report.

2.4 Data Collection Tools

The students' midterm chemistry exam scores served as pre-tests, while an adapted version of the iodine-related test questions was used as post-tests, consisting of 15 one-option questions (4 points each) and 10 blank-filling questions (4 points for each blank). The collected data's Cronbach's alpha coefficient based on the standardized term and the KMO (Kaiser-Meyer-Olkin) sampling relevance measure were ensured to be higher than 0.7, indicating that the tests were valid and credible.

A modified version of the TOSRA questionnaire was designed, incorporating four subscales: attitudes to scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, and leisure interest in science. The questionnaire comprised 40 items. Before and after the implementation of the micro-project, the experimental group of students were given this revised questionnaire to evaluate any potential changes in their scientific attitudes. The Cronbach's alpha reliability coefficients for the four dimensions of the modified TOSRA ranged from 0.74 to 0.82, indicating satisfactory reliability for this study[10].

The experimental group conducted a semi-structured interview with selected students to explore their perceptions and attitudes towards the MPBL integrated classroom after the intervention. The interview consisted of three questions, inquiring about the students' feelings towards MPBL, specific enhanced skills, and suggestions for this project improvement.

2.5 Data Analysis

As the number of samples was greater than 30, the Kolmogorov Smirnov test was used to determine normality. The normality evaluation tests determined that the groups showed a normal distribution. The research data were analyzed with the SPSS 26.0 program. The pre-test and post-test results from the experimental and control groups were analyzed using the independent samples t-test. The pre-test and post-test results from the experimental group in the modified TOSRA test were analyzed using the paired samples t-test.

3. Research Results

3.1 The Effect of the MPBL on Academic Achievement

To compare the academic achievement of the experimental group and control group, a pre-test was conducted before the MPBL intervention began. The independent t-test results are presented in Table 1.

Table 1 Independent t-test Results on Academic Achievement Pre-test Scores of Experimental and Control Groups.

Groups	N	Mean	SD	df	t	p
Experimental	35	82.97	4.53	68	1.327	.124
Control	35	82.63	3.26			

As can be seen from Table 1, the result of the experimental group (M=82.97, SD=4.53) and control group (M=82.63, SD=3.26), p>0.05. It indicates that the post-test scores of the two groups are not significantly different before impletmented MPBL intervention.

A post-test was conducted to the experimental and control groups after MPBL intervention for assessing their academic achievement. The results of the t-test are presented in Table 2.

Table 2 Independent t-test Results on Academic Achievement Post-test Scores of Experimental and Control Groups.

Groups	N	Mean	SD	df	t	p
Experimental	35	89.24	3.47	68	6.327	.000*
Control	35	86.62	4.21			

As can be seen from Table 2, the result of the experimental group (M=89.24, SD=3.47) and control group (M=86.62, SD=4.21), p<0.05. This indicates that the test scores of the experimental group students were significantly higher than those of the control group students, demonstrating a significant difference in the learning levels between the two groups.

3.2 The Effect of the MPBL on Attitude towards Science Lesson

Table 3 The results of students' scientific attitudes measured by the modified Test of Science-Related Attitudes (TOSRA) (N = 70)

Scales	Number of items	Pre-test mean (sd)	Post-test mean (sd)	t-value
Attitudes to scientific inquiry	10	30.12(2.56)	32.42(2.13)	0.97
Adoption of scientific attitudes	10	32.45(3.42)	33.97(3.98)	0.79
Enjoyment of science lessons	10	28.76(2.94)	33.24(1.43)	1.74
Leisure interest in science	10	27.41(3.87)	31.19(2.59)	0.85

As can be seen from Table 3, the results show that after the implementation of the 'iodine extraction from kelp' micro-project in teaching, students' scientific attitudes have been significantly improved statistically.

3.3 Student Interview Results

To better understand student experiences and perceptions of MBPL, 8 students from the experimental group were randomly selected for a semi-structured interview. Some representative responses from the interviewees were presented below:

Question 1: What were your feelings after participating in this micro-project?

Answer 1: Throughout the entire process of the micro-project, I felt engaged by the experiments and tasks. I can think actively and focus on the experiments and group discussions.

Answer 2: I feel enjoy this micro-project. The classroom atmosphere was lively, and our group members cooperated well, actively expressing their ideas. It was great to verify our ideas through experiments as well.

Question 2: What abilities do you think improved after participating in MPBL?

Answer 1: I think my problem-solving abilities have improved. Unexpected events often happened during experiments. For example, when using the iodometric method to determine the iodine content, the solution first turned colorless, then blue, and back to colorless after adding $Na_2S_2O_3$. Through literature review and group discussions, we discussed that it was due to rest H_2O_2 in the solution, which allowed us to further improve the experiment. This process left a deep impression on me.

Answer 2: I feel that my practical skills in doing experiments have improved. Once a procedure is outlined, I can quickly carry out the experiment without needing to refer to the lab manual as before.

Question 3: What is your view on MPBL? Any suggestions?

Answer 1: I hope we can have more micro-projects in chemistry classrooms in the future. I can gain more in micro-projects classrooms and I don't need to spend extra time memorizing chemical knowledge. Because the entire process of the micro-project leaves a lasting impression.

Answer 2: Consulting materials and engaging in group discussions can sometimes be time-consuming. Sometimes, we can't tell if the information is correct as well. Therefore, timely guidance from teachers is necessary.

From the interview results, it is evident that the implementation of 'iodine extraction from kelp' micro project has had a positive impact on students' chemistry learning. Students are able to participate more actively in class, express their ideas, and feel the process of actively connecting with knowledge. By setting up questions and tasks within the micro project, students have improved their analytical and problem-solving abilities. Students hope to engage in more micro projects in future classes, as they have shown a greater enthusiasm and demand for micro project-based classes. However, teachers should pay attention to providing timely guidance and support to help students establish connections between knowledge.

4. Conclusions

This study aimed to investigate the impact of implementing the MPBL teaching method in high school chemistry classrooms on students' academic performance and scientific attitudes. Intervention measures were taken during the learning of the properties of iodine elements. The experimental group utilized a 'iodine extraction from kelp' micro project teaching method, while the control group employed traditional experimental teaching method. A comparison of pre-test scores revealed that before the teaching intervention, there was little difference in the academic levels and scientific attitudes between the two groups. However, the experimental group exhibited significantly better academic performance compared to the control group after this micro project. The experimental group students have high post-test scores in a modified test of TOSRA after engaging in this micro project, indicating a positive impact of the MPBL on students. The interview results from the experimental group indicated that students had a positive experience with this micro project, which ignited their interest in learning and initiative, enhanced problem-solving abilities, and improved knowledge retention. Therefore, the MPBL teaching method is considered an effective approach for improving students' academic performance and scientific attitudes. It is important to note that for the MPBL teaching method to be most effective, teachers should provide scaffolding, necessary support, and guidance to ensure the smooth progress of projects.

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