THE DEVELOPMENT OF LEARNING ACHIEVEMENT IN CHEMISTRY ON CHEMICAL REACTIONS USING AN EXPERIMENTAL METHOD FOR YEAR ONE HIGH SCHOOL STUDENTS

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This study investigated the efficacy of an experimental method for improving learning achievement and satisfaction in first-year high school chemistry. Thirty students from a high school in Yinchuan, China, were randomly assigned to participate in the research, which utilized a pre-test/post-test group design. The research used four lesson plans focusing on chemical reactions, specifically between the metal sodium and its compounds. These lessons were validated for effectiveness using the 80/80 criterion. Additionally, a chemistry achievement test and a student satisfaction questionnaire were employed, both demonstrating appropriate difficulty and discrimination indices and high reliability.

The results demonstrate that the students learning achievement in chemistry significantly improved after using the experimental method. The mean score before studying was 14.90 (SD = 2.04), while the mean score after studying was 18.43 (SD = 2.06). This difference was statistically significant at the .05 level.

Furthermore, the students expressed high satisfaction with the experimental learning approach. The overall satisfaction score was 4.64 (SD = 0.49), and specific aspects like interest and motivation and the perceived usefulness of the method received even higher ratings. This study suggests that utilizing experimental methods as part of the chemistry
curriculum can effectively enhance learning achievement and positive student attitudes towards the subject, particularly in first-year high school students.

**Keywords:** experimental method; learning achievement; student satisfaction; year one high school students

**Introduction**

Chemistry classes in high school were divided into two parts. The first part was conceptual chemistry teaching in high school, which was a large part of conceptual chemistry teaching in high school. It was the most important and difficult content of teaching and the prerequisite for building the subject-knowledge system.

The second part was a chemical experiment, which mainly aimed at observation, analysis, comparison, and application of rational knowledge such as life phenomena and chemical facts, reflected the nature and laws of chemical things and phenomena, and helped students learn and master chemical knowledge intuitively (Lin, 2023).

Guo et al. (2014) found that chemistry experiments, as practical courses for the knowledge learned in high school, greatly ensured students' practical ability and thinking ability. Many students were hindered by the neglect of experimental thinking in school. At the same time, students' ability to create independently was suppressed, which led to problems in high school chemistry experiment classes and affected students' achievement in chemistry.

More than 10 years later, experts and scholars realized that chemical experiments played an irreplaceable role in students' mastery and understanding of chemical knowledge (Jin, 2021). British students went to the laboratory on average three times a week for about three hours, and chemistry experiments took up about one-third of the total chemistry lessons (Deng, 2003).

Judging from the status and importance of the above issues, experimental methods were used to guide students to improve their chemistry scores and master knowledge and skills through appropriate learning arrangements.

**Research objectives**
- to compare high school and year 1 students learning achievement in chemistry using an experimental method;
- to study year 1 high school students satisfaction with using an experimental method in chemistry.

**Research hypotheses**
High school year one students had statistically significantly higher post-learning achievement with experimental teaching methods than before learning at .05.

Students' satisfaction with the experimental method was at a high level.

**Literature review**

After the founding of the People's Republic of China in 1949, a new education system was established and was constantly reformed and improved, which led to great development
and improvement in China's chemistry education. Basic chemistry education had been implemented from middle school, from the third grade of junior high school to the third grade of senior high school, with a total of 380~430 credit hours (Chemistry Education in China, 1862).

Compared to other countries, China was relatively late in studying chemistry education. In China, the curriculum for teaching chemistry in full-time middle schools was formulated in 1978, in which chemistry experiments accounted for 14% of the total teaching hours in chemistry classes. In the 1980s, chemistry experiments accounted for 17% of chemistry teaching hours, but they were mainly demonstration experiments.

By the end of the 1990s, chemistry was inseparable from real life, and some small chemistry experiments related to life were also conducted in experimental classes. Based on the original curriculum, the 2003 standard emphasized the relationship between experimental teaching and scientific investigation and its importance in chemistry teaching.

The 2017 edition of the standard again emphasized the importance of experimental teaching in chemistry. The 2018 edition of the standard suggested cultivating students' ability to conduct scientific inquiry. Chemistry was an experimental science, and compared with the teaching of chemistry theory, it was intuitive, practical, designed, and innovative.

Chemistry experiment teaching could cultivate students' various abilities, such as observation ability, practical ability, innovation ability, data processing ability, computing ability, and the ability to analyze and solve problems. It was related to whether students could master general chemistry knowledge and related skills, whether they could effectively master scientific thinking methods, and whether they could develop good scientific habits and qualities (Guo et al., 2014).

In 2016, the reform of chemistry textbooks was carried out, which mainly involved the adjustment of examination content and policy changes. In terms of examination content, chemistry focused on basic knowledge, thinking methods, and scientific literacy and strengthened the topic setting closely related to actual life. Some complicated, difficult, and less applicable knowledge points were eliminated.

In the new version of the 2019 Human Education Edition, the intensive experiment section was highlighted, allowing students to strengthen their understanding through practice and cultivate their 'open thinking ability, practical ability, and communication ability to improve their chemistry performance.

After the third plenary session of the 11th Central Committee of the Communist Party of China in 1978, education was corrected, adjusted, and reformed, and it made great progress. By the mid-1980s, there were about 100,000 ordinary middle schools in China, with about 50 million students and about 170,000 middle school chemistry teachers.

The basic education of chemistry was widely popularized. There were 1,056 institutions of higher learning in China, with about 22,000 chemistry professors, associate professors, lecturers, teaching assistants, and teachers. About 250 institutions of higher learning across the country had set up departments of chemistry or applied chemistry.

**Experimental method**

The influence of experimental pedagogy was almost all over the major capitalist countries in Europe and America, especially in France and the United States. France, the United States, the Soviet Union, Japan, and other countries had translated and published
experimental pedagogy, and some countries had established educational research institutes
and experimental schools.

Therefore, under the influence of some international schools, China began to carry out
curriculum reform in 2003, giving more hours to chemical experiments and influencing
students' interest in chemistry through experiments.

According to the curriculum standard for general high school chemistry compiled by
the Chinese Chemistry Curriculum Standard Development Group (2004), from the
perspective of teaching epistemology, a chemistry experiment is an essential method of
perceptual cognition. Chemical experiments could make students experience the general
process of scientific experiment learning and experiment method.

From the three dimensions of students' scientific literacy development (knowledge and
skills, process and method, emotional attitude and values), chemical experiments not only
had epistemology and methodology, but they could also stimulate students' interest in
chemical learning, create a lively chemistry teaching situation, transform students' learning
styles, and develop scientific inquiry abilities for the implementation of the "emotional
attitude and values" goal (Zhang & Luo, 2021).

At the same time, in China's high school chemistry curriculum standards, chemistry
experiments were distributed in chemistry 1, chemistry 2, and elective books (Chemistry and
Life, Principles of Chemical Reaction, Chemistry and Technology, Organic Chemistry
Foundation, Material Structure and Properties), among which there were 41 required courses
(chemistry 1, chemistry 2). There was also a particular experimental chemistry module in the
elective, providing ten chemical experiments or inquiries. In the "standard content" and
"activities and experimental inquiry" of high school chemistry courses, there was much
content related to chemistry experiments that were involved.

According to the statistics, the content related to chemical experiments accounted for
36.30% of the total items of the "content standard," and the chemical experiment activities
accounted for 40.74% of the total number of "activities and research recommendations."
From these data, chemical experiments in chemistry textbooks in China have become an
essential part of high school chemistry teaching. Chemical experiments as a separate module
in experimental chemistry, in which it could be seen that chemical experiments in high
school chemistry course content occupied a critical position and more illustrated the use of
chemical experiments, could help students improve their chemistry performance (Liu, 2003).

**About the theoretical basis of the experimental teaching method**

Three dimensions were mainly used to illustrate the goal of teaching using the
experimental method. Chemistry experiments and teaching were based on helping students
adapt to the needs of modern life and future development.

Therefore, the general teaching goals were divided into skill goals, inquiry goals, and
cognitive goals as follows:

1) Skills target,
2) Explore the goal,
3) Cognitive goals.

In the General High School Chemistry Curriculum Standard (Experiment), the
cognitive goals of chemistry experiments for students mainly included:

(1) developed students' interest in learning chemistry and being willing to experience
the mystery of material changes.
(2) had the enthusiasm to participate in chemical science and technology activities and were able to apply chemical knowledge to life and production. Made reasonable judgments on social and life issues related to chemistry.

(3) made students pay attention to the hot social issues related to chemistry and gradually formed the idea of sustainable development.

(4) developed a scientific attitude of seeking truth from facts, being brave in innovation, and being positive in time, and established a sense of responsibility and mission to study hard for human civilization and social progress.

**Experimental teaching method**

In addition to observing the principles of chemical experiments, teachers also needed to pay attention to the following principles when designing chemical experiments (Que et al., 2011):

1) Principle of direct observation.
2) The principle of process.
3) Principles of development.

The teaching process focuses on experiments in this research.

Wang (2019) had discussed the application of micro-chemical experiments using WeChat video technology for classroom demonstration experiments. About general first-class chlorine gas, WeChat's video features and students' practical experiments have been used to cultivate students' observation and practical skills.

The procedure was as follows:

**Achievement**

Kong (2008) scholars believed that abnormal phenomena of chemical experiments had become a hot topic in the chemistry of the college entrance examination, and it was also a difficult point for students because experimental inquiry was an important investigation content of the college entrance examination of chemistry.

Therefore, paying attention to the abnormal phenomena of chemical experiments was conducive to improving students' performance.

Then it was necessary for students to understand the experiment after the actual operation of the experiment before they could better complete the chemical experiment investigation.

**Related research and studies**

Liu (2003) believed that the design of chemical experiments should have been determined according to the teaching situation, which was not simply to teach students how to do experiments but to solve how to do it from the two perspectives of epistemology and methodology and what teaching methods and strategies should have been adopted to ensure the realization of the function and value of chemical experiments.
Research Design

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Treatment</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample group</td>
<td>O1</td>
<td>X</td>
<td>O2</td>
</tr>
</tbody>
</table>

Notes: O1: Pretest  
O2: Posttest  
X: Treatment (Learning activities using an experimental teaching method)

Figure 1 – Research design  
(made by co–authors)

Research instruments

Lesson plans

The researcher created a chemistry lesson plan by studying information from related documents, which consisted of studying the details of the Chinese compulsory education curriculum in high school chemistry.

They also studied the method of creating a teaching plan according to the experimental teaching method as a guideline for creating the teaching plan. Then, they created a chemistry lesson plan with an experimental teaching method, dividing it into 4 lesson plans consisting of 8 sessions.

Achievement test

To create the Chemistry Achievement Test, it was designed as a multiple-choice type with four options for each of the 30 questions. The steps involved studying the compulsory education curriculum in China, high school chemistry, and reviewing the theory, principles, and guidelines for creating an achievement test.

A test was then created to measure learning achievement. It was structured as a multiple-choice test with 4 options, each with only one correct answer, covering all the key content used in the research, totaling 60 questions.

The experts' reviews were recorded, and an acceptable Index of Item Objective Congruence (IOC) of .50 or higher was sought. The results of the inspection found that the acceptable Index of Item Objective Congruence (IOC) was 1.00.

This indicates that the questions and options of the achievement test are congruent and appropriate.

Then, the chemistry achievement test was improved according to the advice of the experts. The revised Chemistry Achievement Test was then taken for a tryout with 30 high school students who had already studied the reaction of sodium.

Afterward, the test scores were checked by awarding 1 point for each correct answer. Questions that were answered incorrectly or not answered were given 0 points.

These were analyzed to find the difficulty (p) between 0.20-0.80 and the discriminating power (r) between 0.20-1.00, after which 30 multiple-choice items were selected for use with the sample.
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Table 1 - Criteria for interpretation of correct answer analysis for test difficulty (p)
(made by co-authors)

<table>
<thead>
<tr>
<th>Test difficulty (p)</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.81-1.00</td>
<td>It's that simple</td>
</tr>
<tr>
<td>0.60-0.80</td>
<td>Quite simply</td>
</tr>
<tr>
<td>0.40-0.59</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.20-0.39</td>
<td>Quite difficult</td>
</tr>
<tr>
<td>0-0.19</td>
<td>Very hard</td>
</tr>
</tbody>
</table>

Table 2 - Criteria for interpreting the results of the correct answer analysis of the test (r)
(made by co-authors)

<table>
<thead>
<tr>
<th>Discriminant power of the exam (r)</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.60-1.00</td>
<td>Very good</td>
</tr>
<tr>
<td>0.40-0.59</td>
<td>Good</td>
</tr>
<tr>
<td>0.20-0.39</td>
<td>Fairly</td>
</tr>
<tr>
<td>0.10-0.19</td>
<td>Relatively low, should be improved</td>
</tr>
<tr>
<td>0-0.09</td>
<td>Very low, should improve</td>
</tr>
</tbody>
</table>

**Questionnaire**

The theory, principles, and guidelines for constructing an opinion questionnaire were studied. Questions or guidelines for asking and constructing questions were created by constructing an opinion questionnaire as a 5-level evaluation scale based on the concept of the Likert scale, consisting of:

- Level 5 means most satisfied.
- Level 4 means very satisfied.
- Level 3 means moderately satisfied.
- Level 2 means less satisfaction.
- Level 1 means least satisfied.

To assess the reliability of the skills test and questionnaire, the researcher used Cronbach’s alpha.

Reliability refers to the consistency of results obtained from repeated measurements using the same test instrument. Therefore, the researchers plan to conduct a questionnaire survey with another 30 students in the same grade to evaluate the reliability of the instrument.

**Validity and reliability of the research instrument**

**Language and content validity**

To check the appropriateness of the language and content validity of the lesson plan, the Chemistry Learning Achievement Test, and the opinion questionnaire, the researcher followed the steps below:
-identified the objectives of the research instrument. What were the specific concepts, skills, or knowledge that the instrument was designed to measure?
-reviewed the instrument carefully to ensure that each item was aligned with the objectives. Were the items clear, concise, and easy to understand? Did the items cover all of the relevant content?
-asked a group of experts (e.g., content experts, curriculum and instruction experts, measurement experts, and evaluation experts) to review the instrument and provide feedback. Did they agree that the items were aligned with the objectives? Did they have any suggestions for improvement?

**Suitability and consistency of the lesson plan**

To check the suitability and consistency of the lesson plan, the researcher followed the steps below:
-identified the key learning objectives for the lesson. What were the specific concepts, skills, or knowledge that students were expected to learn by the end of the lesson?
-reviewed the lesson plan carefully to ensure that each activity was aligned with the learning objectives. Were the activities appropriate for the students’ age and developmental level? Did the activities provide students with opportunities to practice and apply the concepts they were learning?
-used the 80/80 criterion analysis to ensure that 80% of the learning objectives were covered in 80% of the lesson time.

**Chemistry learning achievement test**

To check the Chemistry learning achievement test, the researcher used the following analyses:
-Difficulty (p): this analysis measured the proportion of respondents who answered an item correctly. A difficulty level of 0.5 indicated that half of the respondents answered the item correctly. A difficulty level of 0.75 indicated that 75% of the respondents answered the item correctly.
-Discriminatory power (r): this analysis measured how well an item discriminated between high-performing and low-performing respondents. A discriminatory power of 0.30 or higher was considered to be acceptable.
-Reliability: this analysis measured the consistency of the results of a research instrument over time. There are a number of different reliability coefficients that can be used, such as Cronbach's alpha and inter-rater reliability. A reliability coefficient of 0.70 or higher was considered to be acceptable.

**Ethical approval**

To conduct the study at the school, the researchers obtained approval documents from a high school in Yinchuan.

Since the participants in this study were between 16 and 17 years old, the researchers also obtained permission from the school’s responsible department and the parents.

**Confidentiality**

The investigator kept all biological data and responses to the questionnaire confidential. The researcher deleted all the data after the study was completed.
Analysis of students' learning achievement

This section compares the academic performance of first-year high school students in China who use experimental methods to learn chemistry. The results of the study were obtained through pre- and post-tests. For fairness, two evaluators were also involved.

By comparing the difference between the scores before and after the study using a dependent t-test, the following results are shown in the Tab.3.

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Mean difference</th>
<th>T</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Group</td>
<td>14.90</td>
<td>18.43</td>
<td>3.53</td>
<td>20.65*</td>
<td>0.000**</td>
</tr>
</tbody>
</table>

Significance level (p): <0.05=significant

The mean scores of the pretest and posttest were 14.90 and 18.43, respectively, as shown in Tab. 4. The results in Tab. 4 showed that the group's mean posttest score (x = 18.43) was higher than the mean pretest score (x = 14.90), with a mean score difference of 3.53. Research clearly shows that before using experimental methods to learn chemistry, students' academic performance is lower than after using them. The standard deviation of the pretest was 2.04, and the standard deviation of the posttest was 2.06. The comparison of all these scores confirms the validity of the academic performance of first-year high school students in China.

The researcher also created a graph to show the comparison of the pre-test and post-test scores. The graph in Fig. 2 shows that the mean student score on all eight worksheets was above 70%.
This is because the worksheets at the end of the study plan have been reviewed to ensure their appropriateness and consistency with the study plan and are therefore considered valid. Students can answer questions on assigned worksheets.

The highest average student score in was 91%, and the lowest average student score was 73.3% (Fig 3).

A five-level scale questionnaire was used to collect quantitative data and study students' attitudes toward using experimental methods to learn chemistry. The questionnaire has 14 questions in total. It was divided into Part A (interest and motivation), Part B (engagement), and Part C (the function of the experimental method on the students).

The questionnaire was administered to all 30 (N = 30) study participants. The survey results were analyzed using descriptive statistics (mean and standard deviation).

Table 4 – Students' overall views on the development of chemistry performance using the chemistry experiment method (made by co-authors)

<table>
<thead>
<tr>
<th>NO</th>
<th>Part</th>
<th>Mean</th>
<th>S.D.</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PART A: Interest&amp;Motivation</td>
<td>4.68</td>
<td>0.49</td>
<td>Highest</td>
</tr>
<tr>
<td>2</td>
<td>PART B: Engagement</td>
<td>4.60</td>
<td>0.52</td>
<td>Highest</td>
</tr>
<tr>
<td>3</td>
<td>PART C: The function of the experimental method on the students</td>
<td>4.65</td>
<td>0.48</td>
<td>Highest</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>4.64</td>
<td>0.49</td>
<td>Highest</td>
</tr>
</tbody>
</table>

It can be found that year one high school students are generally satisfied with the development of their learning performance in chemical reaction experiments, with an average of 4.64 and a standard deviation (S.D. = 0.49).
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When considering opinions by aspect, it was found that students were most satisfied with the aspect of interest and motivation at the highest level, with an average of 4.68 and a standard deviation of (S.D. = 0.49).

Second, the aspect of the function of the experimental method on the students had an average of 4.65 and a standard deviation of (S.D. = 0.48), respectively, which is consistent with the second research hypothesis set.

Among the three parts, Parts A and C have higher average scores, with average scores of 4.68 and 4.65 and standard deviations of 1.14 and 1.23, respectively. Part B has the lowest average score, with an average score of 4.60 and a standard deviation of 0.9.

Nonetheless, considering the overall average score of 4.64, the researchers believe that the chemistry experiment teaching method can effectively improve the chemistry performance of first-year high school students.

Conclusion

The learning achievement of students who studied about learning chemistry with experiments in general was found to be that the mean score before studying was (= 14.90) and the standard deviation was (S.D. = 2.04), and the mean score after studying was (= 18.43) and the standard deviation was (S.D. = 2.06). The difference was statistically significant at the.05 level, with the post-test scores being higher than the pre-test scores.

The opinions of students on the development of chemistry performance using the chemistry experiment method in general were the most satisfied, with a mean score of (= 4.64) and a standard deviation of (S.D. = 0.49). When considering the opinions of each item, it was found that interest and motivation had the highest level of satisfaction, with a mean score of (= 4.68) and a standard deviation of (SD = 0.49).

The next highest was the function of the experimental method on the students, with a mean score of (= 4.65) and a standard deviation of (SD = 0.48) had the highest level of satisfaction, with a mean score of (= 4.60) and a standard deviation of (S.D. = 0.52).

Discussion

From the results of the research on pre-test and post-test scores and questionnaire survey satisfaction, the following conclusions can be drawn:

Students’ learning achievement

The results of the study showed that the performance of students who used experimental methods to learn chemistry improved significantly after the intervention (p <.05). The students’ opinions on the development of chemistry through experiments were generally positive, with the highest level of satisfaction. In the discussion, most students felt that the intervention helped them improve their grades.

Students’ satisfaction

1) The three sections A, B, and C in the questionnaire were all rated as "highest" levels. No item was rated as “strongly disagree.”

2) The descriptive statistical analysis results of the questionnaire show that students are relatively satisfied with the experimental method for improving chemistry scores. Most
notably, none of the questions were marked as "moderately" or "strongly disagree," which strongly indicates students' positive satisfaction with the use of experimental methods in learning chemistry.

3) Most students also believed that using experimental methods improved their understanding and analytical skills in chemistry learning.

The results showed that only the experimental significance questions in the questionnaire had lower scores, indicating that students were willing to explore chemical experiments that were more in-depth and closer to life. Looking back on the teaching process, students showed a high degree of concentration and participation in the course and successfully completed the teaching plan. The classroom atmosphere is always relaxed and happy, which greatly confirms the students' positive satisfaction with the fun of class.

Recommendations

This study was limited to 30 first-year Chinese high school students in Yinchuan, China. Similar studies with larger sample sizes can be conducted in different regions of China, which would be very valuable for similar studies to validate and ensure the credibility of this study. But it is only suitable for students in the first grade of high school. If you want to try it with students of other age groups and in countries other than China, please make different adjustments according to the teaching materials and student acceptance. For example, in other high schools in China, it is necessary to examine the complexity of experiments and the time crunch facing the college entrance examination.

Therefore, except for the first grade students, teachers are asked to give priority to more practical experiments.

Future research

Compared with other teaching methods in chemistry teaching, the use of experimental methods is more effective in stimulating students' interest and is also very effective in improving students' academic performance. It is recommended that other chemistry teachers try using experimental methods to teach chemistry.

Whether the experiments mentioned in this article are required to be completed in the textbook or experiments designed by guiding students, the important thing is to choose experiments that are suitable for the site, meet the students' experimental level, are related to the course or topic being studied, and provide appropriate guidance. In addition, ensure the operability and safety of the experiment.

The disadvantage of traditional chemistry is that in the classroom, students are always in a passive position, passively accepting theoretical knowledge from the teacher, which reduces students' enthusiasm for learning chemistry.

Therefore, it is not enough to only use experimental methods. We can add an evaluation system to evaluate activity performance, experimental procedures, teacher attitudes, etc. Only in this way can the experiments and teaching in the course effectively promote students' comprehensive development in knowledge, skills, process methods, and emotional attitudes.
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