**Development of an augmented reality system for learning the molecular structures of chemical compounds and calculating the coefficients of balanced equations for chemical reaction**

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The purpose of this research is to establish a card-based augmented reality (AR) system to assist students in learning chemical knowledge. The research objects are second-year students in a middle school, and the learning contents are the basic structures of chemical compounds and calculating the coefficients of balanced chemical equations for chemical reaction.

Traditionally, middle school students conduct learning by reading teaching materials with texts and pictures and skills of hand calculations. They also need to memorize the coefficients of some complex equations and imagine the microscopic view of molecular structures to understand the abstract concepts in chemical reaction. As a result, students have less experimental experience and practical implementation, which may cause difficulty in further learning and cognition. The proposed system can visualize the abstract concepts through AR operation, including the molecular structures and reaction process, by scanning cards to replace paper and pencil calculations. Combining with the Predict-Observe-Explain (POE) teaching strategy, it is expected that the improved cognition can be achieved through the steps of repeated prediction, observation, and explanation.

A quasi-experimental research was conducted to investigate the learning effectiveness of students after using the AR system. The control group performed learning in the traditional way while the experimental group learned using the AR system, with 50 students in each group. Achievement tests were taken before and after the teaching experiment, and questionnaires were filled out to explore the learning motivation, cognitive load, and technology acceptance of students. The statistical analysis of the test results is used to understand the impact of different approaches on the learning efficiency of students, and the questionnaire results can provide teachers with more in-depth understanding of innovative ideas in teaching chemistry.

Keyword:  Augmented Reality (AR), Predict-Observe-Explain (POE), Learning Effectiveness, Cognitive Load, Learning Motivation