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# 개념문제의 이용이 학생들의 화학 이해도와 화학에 대한 흥미도에 미치는 효과

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# A Study of the Effect of Conceptual Questions on Students' Understanding and Students' Interest in Chemistry

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**요 약.** 학생들이 수리문제에 포함되어있는 화학적인 개념을 이해하지 못하고 기계적으로 수리문제를 해결하는 것으로 알려졌다. 이러한 문제점을 해결하기위한 한가지 방법으로 강의의 예제나 과제물의 퀴즈문제로서 개념문제를 이용하여 화학에 대한 개념이해와 흥미도 증진을 알아보기 위해 기체,고체,액체,용액을 포함하는 내용으로 수리문제와 개념문제를 개발하여 80명의 대학생들에게 투여하였다.이 논문의 연구는 다음의 결과를 암시하였다. 1) 우리나라 대학생들도 수리문제 해결력보다는 개념문제의 해결에 어려움이 있다. 2) 이 연구에서 적용한 5차례의 단기간 개념문제의 사용으로는 개념이해의 효과가 뚜렷하게 나타나지 않았다. 3) 하지만 5차례의 단기간 개념문제의 사용으로도 개념문제에 대한 흥미와 관심에 대한 효과가 높았다. 4) 그리고 개념문제를 사용한 집단이 수리문제를 사용한 집단보다 높은 출석률을 보여주었다. 5) 높은 출석률과 학생들이 개념문제에 대한 흥미를 보여줌으로써 개념문제의 사용은 긍정적인 교육효과를 시사하고 있다.

**주제어:** 개념문제이용, 높은 출석률

**ABSTRACT.** Many reports say that students can solve algorithmic problems but cannot answer questions based on the concepts behind the problems. This paper studied the effect of using conceptual questions as part of the lecture and homework assignments in an attempt to encourage general chemistry students to improve their understanding of chemistry concepts and to increase their interest in the chemistry. The performance of a treatment group (N=40) and a control group (N=40) were measured using an instrument consisting of ten paired conceptual and algorithmic questions which cover gases, liquids, and solids. The research implies that 1) As reported by others, the students in our sample solved algorithmic problems more effectively than they answered conceptual questions. 2) A short term intervention using conceptual questions is not effective in improving conceptual understanding when compared to a similar intervention using algorithmic problems. 3) But, it is effective in improving interest in science to use a short term intervention with conceptual questions when compared to a similar intervention using algorithmic problems. 4) Students in the conceptual treatment class exhibited higher attendance than students in the treatment group. 5) Based on class attendance data and student survey responses, it appears that students in the conceptual treatment group responded positively to the use of conceptual questions.

**Keywords:** Using Conceptual Question, Higher Attendance

## INTRODUCTION

Many chemists believe one of the ultimate goals for chemistry learning is to have students succeed in solving problems by understanding chemical concepts. However, students have difficulty in this area. A review of problem-solving research[1] has shown that one of the main reasons students have difficulty solving chemistry problems is they do not understand the concepts needed to solve the problems and many studies have shown that chemistry students hold inappropriate concepts.[1-6]

Several studies have reported that college students have a gap in their ability to solve algorithmic problems and conceptual questions.[7-13] Noh[2] has found that Korean college students have greater success in solving algorithmic chemistry problems than in solving conceptual chemistry problems. Other studies have found the same gap for US and Israeli students.[8-13] Students appear to solve problems by memorizing algorithms instead of developing the understanding necessary to solve them. Thus, chemical educators' assumption that being able to solve an algorithmic problem is equivalent to understanding a concept may not be justified.

Students need to do more than memorize definitions and practice solving problems to develop a complete understanding of chemistry. One barrier to convincing them to change from memorization and practicing algorithms to thinking conceptually is the extent of their prior experience thinking algorithmically. Our students have used memorization and algorithms for many years before they come to a first year college general chemistry course. They already have in place a problem-solving model that seems adequate to them. Students are reluctant to discard an old, familiar idea for a new and unfamiliar one. They will hold tenaciously to the older concepts as long as possible,[14-15] and changing their beliefs about the most effective way to learn chemistry is similar to trying to change misconceptions.

One guide to how we can change students' understanding of how to learn chemistry comes from the constructivist model of learning. Although facts can be transmitted from instructor to learner, understanding is actively built by learners.[16-18] From the constructivist perspective,[17] understanding consists of collections of knowledge of concepts and actions that learners have found they can apply successfully in a given situation. If their knowledge leads to actions that are successful, they believe that knowledge to be valid. Learners grow to view knowledge as invalid if it does not produce successful results. If they are never in a situation where their knowledge fails, students have no need to change. Because students already have in place a learning and problem-solving model that has worked for them, telling students that their understanding of how to learn chemistry is wrong is unlikely to have any effect. In order to change their understanding of how chemistry should be learned, students need to experience situations where their style of learning does not work when they expect it to.

This paper is hypothesized that the use of conceptual questions in class and for homework would provide situations where students can recognize that they need to learn differently. This hyposesis is also based on principal teaching method that students learn as they are tested.[19] Conceptual questions are questions that cannot be answered with a memorized answer because they require that a student understand the chemical ideas associated with the question. Usually these questions are non-mathematical. They require students to express their understanding and, by doing that, the students must evaluate that understanding. Many conceptual questions involve a combination of the macroscopic, particulate, and symbolic forms of representation used to represent and translate chemical information. If students have an opportunity to think about chemical concepts in response to conceptual questions and if they are tested with conceptual questions, their learning style will change to include a focus on understanding the concepts.

Several references[20-23] suggest that classroom use of conceptual questions can increase student understanding. Herschback notes in the preface to *Voyages in Conceptual Chemistry*[21] that concept questions help students improve their qualitative reasoning. This will also strengthen their ability to handle numerical problems that require understanding. Garratt et al.[22] point out that concept questions can reveal differences between those who think of chemistry as a process and those who regard it as knowledge to be remembered. Landis et al.[23] indicate that the use of conceptual questions increases students' enthusiasm for lecture, provides real-time feedback, involves peer-instruction, increases attendance, and decreases attrition. Oral assessments of students' competence consistently demonstrates a higher order ranking for students who take courses that are rich in pedagogical techniques such as interactive lectures and peer instruction provided by the use of conceptual questions in the classroom.[24]

This report describes a study using conceptual questions in a general chemistry course in an attempt to encourage students to improve their understanding of chemistry concepts.

## RESEARCH METHOD

### Developing an achievement test

The achievement test consisted of 10 pairs of conceptual questions and algorithmic problems which covered gases, solids, liquids, and solutions. Eight of the question pairs came from the literature[8-12] and the other two pairs were developed by the investigator. These two pairs were checked by one faculty member and three graduate students. Two examples of algorithmic problems and conceptual questions follow, with the correct answer indicated by an asterisk.

*Colligative Properties: Algorithmic problem*[11]

What is the vapor pressure of 1000.0 g of a water solution at 25°C which contains 224.0 g of the nonvolatile solute ethylene glycol, $C_2H_6O_2$? The vapor pressure of pure water at this temperature is 23.76 torr.

(a) 1.38 torr
(b) 1.47 torr
(c)*21.9 torr
(c) 22.7 torr

*Colligative Properties: Conceptual question*[11]

Consider a solution of water and a nonvolatile solute at some temperature. What combination of conditions would be sure to increase the vapor pressure of the solution?

(a) Raise the temperature and add more solute
(b) Lower the temperature and add more solute
(c) Lower the temperature and add more water
(d)*Raise the temperature and add more water

*Limiting Reagent: Algorithmic question*[8]

A reaction equation can be written to represent the formation of water from hydrogen gas and oxygen gas.

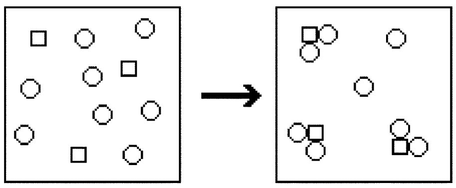
$$2H_2 + O_2 \rightarrow 2\ H_2O$$

For a mixture of 2 mol $H_2$ with 2 mol $O_2$, what is the limiting reagent and how many moles of the excess reactant would remain unreacted after the reaction is completed?

| | Limiting reagent | Excess reactant remaining |
|---|---|---|
| (a) | $O_2$ | 1 mol $O_2$ |
| (b) | $O_2$ | 1 mol $H_2$ |
| (c)* | $H_2$ | 1 mol $O_2$ |
| (d) | $H_2$ | 1 mol $H_2$ |
| (e) | No reaction occurs since the equation does not balance with 2mol $H_2$ and 2 mol $O_2$. | |

*Limiting Reagent: Conceptual question*[8]

The reaction of element X (□) with element Y (○) is represented in the following diagram.



Which equation describes this reaction?

(a) $3X + 8Y \rightarrow X_3Y_8$
(b) $3X + 6Y \rightarrow X_3Y_6$
(c)* $X + 2Y \rightarrow XY_2$
(d) $3X + 8Y \rightarrow 3XY_2 + 2\ Y$
(e) $X + 4Y \rightarrow XY_2$

**Experimental Section**

This research was carried out in a large general chemistry program at a university in Seoul using one class of 80 students whose major is engineering. For the first seven weeks of the 16-week course, the students studied stoichiometry, atomic structure, and chemical reactions. The students took a mid-term exam after seven weeks. The mid-term exam was developed by the 10 instructors of the entire course and scored by 20 teaching assistants, each using the same standard.

After the mid-term exam, the investigator divided one class of 80 into two groups of 40 with equivalent scores on the midterm exam. The same instructor gave the lecture on the treatment group and controlled group. The treatment group was given instruction which included solving two or three conceptual questions from *Voyages in Conceptual Chemistry*[21] during the lecture and was also given the assignment to answer two or three additional conceptual questions as homework following each lecture. The answers to these questions were discussed briefly at the beginning of the next lecture. The control group was given instruction which included solving two or three algorithmic problems from commercial general chemistry textbooks[25-26] during the lecture and was given the assignment to solve two or three algorithmic problems as homework following each lecture. Similar to in the treatment group, the homework was discussed at the beginning of the next lecture. The treatments were used for five lessons: two lessons (two hours) for gases, one lesson (one hour) for liquids and solids and two lessons (two hours) for solutions. After five treatments, an achievement test, consisting of 10 pairs of conceptual questions and algorithmic problems, was given to both groups of students. A free response survey asking students about their feelings about conceptual and algorithmic questions was given at the end of the semester. The results of that evaluation are reported here.

## RESULTS

Student scores were based on 10 points for the conceptual questions, and 10 points for the algorithmic problems. The SPSS statistical program was used for the analysis. Although 80 students were enrolled in the class, only 65 scores were used: 38 from the treatment group and 27 from the control group. I did not use data from the students who were absent for three or more of the five treatments or who were absent on the day the achievement test was given. The average on the mid-term exam was the same for the two groups. And the average on the attendance was 28 when compared with that of the students who were absent for three or more of the five lectures before the mid-term exam in both groups. Thus, we believe the two groups were equivalent at the start of the experiment.

As shown in *Table* 1, students in both the control and treatment groups solved algorithmic problems more successfully than they answered conceptual questions. The difference in scores between the algorithmic and conceptual question are statistically significant for each group, separately, and for the combined population. The differences in scores on the algorithmic problems or conceptual questions between the two groups are not significant (*Table* 2 and 3).

Although the average of the treatment group's scores is a little higher than the control group's scores on both the conceptual and algorithmic ques-

*Table* 2. Comparison of scores between the two groups on conceptual questions

| | M (SD) | F | p |
|---|---|---|---|
| Treatment Group (N= 38) | 7.14(1.66) | 0.199 | 0.657 |
| Control Group (N=27) | 6.96 (1.53) | | |
| Total (N=65) | 7.07 (1.60) | | |

*Table* 1. Comparison of scores between those on conceptual questions (CQ) and on algorithmic problems (AP)

| | M (SD) for CQ | M (SD) for AP | t | p |
|---|---|---|---|---|
| Treatment group (N= 38) | 7.14(1.66) | 8.31(1.07) | 4.132 | 0.000 |
| Control group (N=27) | 6.96 (1.53) | 8.11(1.40) | 2.882 | 0.008 |
| Total (N=65) | 7.07 (1.60) | 8.26(1.21) | 5.017 | 0.000 |

*Table* 3. Comparison of scores between the two groups on algorithmic problems

| | M (SD) | F | p |
|---|---|---|---|
| Treatment Group (N=38) | 8.31(1.07) | 0.674 | 0.415 |
| Control Group (N=27) | 8.11(1.40) | | |
| Total (N=65) | 8.26(1.21) | | |

*Table* 4. Comparison of attendance between the two groups

| | More than 3 times attendance | More than 3 times ttendance ercemtage(%) |
|---|---|---|
| Treatment Group (N=40) | 38 | 95.0 |
| Control Group (N=40) | 27 | 67.5 |

tions as shown in Tables 2 and 3, the results are not statistically different. We can also see that the use of conceptual questions in a five- hour treatment did not significantly improve the performance of the treatment group on conceptual questions, but it did not harm their performance either. But there is a large difference in attendance between the two groups (*Table* 4). Thirty eight students (95%) in the conceptual treatment group attended at least three of the five lecture sessions and took the achievement test, while only 27 (68%) of the students in the control group attended at least three of the five lecture sessions and took the achievement test. The responses in the survey have been counted as positive or negative. Positive responses include: they enjoyed solving conceptual questions, they feel like college students, not high school students, because they were exposed to problems that require higher level thinking, they were challenged with new type questions. Negative response include: they don't like to conceptual question or the question was trivial. The neutral response has been counted for a so-so response. No response has been counted for no writing. Twenty students (50%) in the conceptual treatment showed positive responses while nobody showed a positive response in the control group.

## CONCLUSION AND DISCUSSION

The research conclude that 1) The students in our sample solved algorithmic problems more effectively than they answered conceptual questions. 2) A short term intervention using conceptual questions is not effective in improving conceptual understanding when compared to a similar intervention using algorithmic problems. 3) It is effective in improving interesting in science to use a short-term intervention with conceptual questions when compared to a similar intervention using algorithmic problems. 4) Students in the conceptual treatment class exhibited higher attendance than students in the treatment group 5) Based on class attendance data and student survey response, it appears that students in the conceptual treatment group responded positively to the use of conceptual questions.

Scores from both the treatment group and the control group show that this group of very good students solves algorithmic problems better than they answer conceptual questions. This result is consistent with previous research.[7-13] I did not see an improvement in students' conceptual understanding using conceptual questions for only five lessons. This result might imply that students need to practice more to be comfortable with conceptual questions because these questions are new to them, or it could imply that students need a longer exposure to conceptual questions to recognize that their old methods of learning are not completely successful. These students have successful prior experiences learning chemistry and thinking algorithmically. They already have in place a problem-solving model that seems adequate. But they may need to experience more dissatisfaction with their performance to be convinced that the old methods will not lead to the necessary understanding.

The higher attendance and student comments

*Table* 5. Comparison of student's survey responses.

| | Positive response (%) | Neutral response | Negative response (%) | No response (%) |
|---|---|---|---|---|
| Treatment Group (N=40) | 20 (50%) | 10(25%) | 4(10%) | 6 (15%) |
| Control Group (N=40) | 0 (0%) | 18(45%) | 12(30%) | 10 (25%) |

suggest that students in the conceptual treatment group respond positively to using conceptual questions. Several students told me they enjoyed solving conceptual questions. From the higher attendance and student's responses it appears that students enjoyed the course more when it included conceptual questions. This could be another reason to use conceptual questions; we want students to enjoy their general chemistry course in order to enhance retention in chemistry programs.

The next step in the research is to extend the treatments in order to give students an opportunity to become familiar with conceptual questions and to change their thinking patterns. When we are reminded that high attendance and high interest is related with good achievement, we can expect to improve conceptual understanding with long term intervention using conceptual questions. Instruction using conceptual questions for at least one semester is suggested. In addition, a qualitative study should be conducted to determine if students really do prefer conceptual questions to algorithmic exercises. Sources for conceptual questions are listed in the reference.[21, 22,23,27]

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