Pattern of the University Students' Perception for Unexpected Results and Effect of Problem-Solving Experiments for Change of Perception

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Abstract: The purpose of this study was grouping students' perception types on the unexpected results in experiments, and looking into how the problem-solving experiment affected the change of these perception types. In order to answer this, interview data were analyzed in terms of perception types, and through analysis of questionnaires carried out at the beginning and the end of the semester, the change of perception types was researched.

As a result, perception types of students divided into 'the difference between theory and practice,' 'inexperience of experiment skill,' and 'No reading between lines in manual.' After performing the problem-solving experiment for one semester, the perception of 'the difference between theory and practice' declined, and the desire for 'reading between lines' increased, so the problem-solving experiment influenced on the change of perception positively.

Key words: Unexpected result, problem-solving laboratory, perception type

Ⅰ. Introduction

Among methods for understanding the nature of science and acquiring the scientific inquiry process, one of the directive methods is following scientists' research processes as it is. An experiment is one of the means of scientific research (Tobin, 1990; Hofstein, 2004). In science education, an experiment is to provide the opportunity of participating the processes of research and inquiry for the students, and it plays an effective role as teaching the scientific inquiry process (Tamir, 1997; Shepardson, 1997; Leonard, 1983).

However, current school experiment places emphasis on checking concepts rather than the scientific inquiry process (Germann *et al*., 1996; Kim *et al*., 2006), so it makes student recognize that the experiment is a kind of study methods for understanding (Kim & Song, 2003). Furthermore, teachers often think that they don't have to teach scientific processes, because these processes are acquired and assimilated naturally by progressing instructions and experiments (Brush, 1974).

Therefore, this study was focused on actual scientists' research processes and imitating them as methods of teaching the scientific inquiry process systematically in experiments. The scientist' research processes can be divided up into problem-solving, presenting models, producing the creative ideas, and pseudo-serendipity (Kim, 2010). In examining scientists' research processes, there are justification and the discovery of context (Brush, 1974). From among these, the discovery of context is a process of forming new knowledge or scientific principles, and notions through unexpected results or phenomena in the justification process. In Dunbar's research (Dunbar, 2000), scientists generally suggest these unexpected results are important factors to lead scientific discovery. Also, they said the importance of knowing how to deal with these unexpected results for the scientists. If these unexpected results emerged, the objective should be discovering causes (Dunbar, 1993; Soldatova & King, 2006), and in order to solve the emerging

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situation, the reconstruction of experiments should be repeated. Though these process do not bring an important change, they can be a certain starting point of discovering (Yi & Kang, 2005; Lim & Kang, 2009; Yang etc., 2006; Park *et al.*, 2009).

Most of the students, though, are not familiar with various situations in laboratory, especially, unexpected or strange results. They usually give up the experiment eventually, because they pursue only expected results rather than new discovery. Otherwise they continuously repeat same experiments and might be exhausted. To these students, the experience of scientists' problem-solving processes can be important guidelines to understand inquiry processes, by extension, to recognize the nature of science. The students are quite experienced in following a given process of the experiment. That is the reason why we present the problem-solving experiments to students repeatedly and make the students perform it.

Thus, the purpose of this study is examining how the university students perceive unexpected results, and the reason they get these perception. Also, it is examining the effect of problem-solving experiments on the change of students' perception. Through the inquiry of students' perception, the causes of students' responses on unexpected results can be understood and an effective instruction to convert unexpected results into new discovery can be discussed (Hofstein & Lunetta, 2004).

Ⅱ. Research Methods

1. Subjects and Methods

This study was progressed for 2 years, and participants who were freshman in chemistry education department at H University in Chung-Buk province and took general chemistry experiment were chosen. In the first year, 'combustion of iron' experiment was performed, and students' perception type on the problem situation was analyzed through interview. The next year, new students performed the problem-solving experiments for one semester, and descriptive questionnaires were input to them at the beginning and the end of the semester. Then, the results were analyzed to search for the change of perception types. The descriptive questionnaires and interview were met with students' consent for using as research materials in science education. Interviewees in 1st year are 18 and 2nd year are 18. After survey of recognition, classifying 3 recognition types took considerable time, so the research on the change of perception carried out next year.

2. Collection and Analysis of Data

Bodner and Herron (2002) defined problem-solving is that "What you do, when you don't know what to do," and regarded occurring this situation in the experiment processes as problem-solving inquiry experiment. The problem-solving experiments used in this inquiry were based on the developed experiments (Yi & Kang, 2005; Lim & Kang, 2009; Lee & Kang, 2008). In these experiment, the experimental procedures were given. When students just follow a given procedure, they meet the problem-emerging situation. In order to solve the emerged problems, they need to find a problem, suggest idea and solve problems. The 10 problem solving experiments used in this research were following; density of coke and diet coke, 'Pop' using an antacid agent, determination of mass of $NaHCO_3$ in an antacid, freezing point degression of solution, thin layer chromatography, combustion of iron, determination of acid in beverage, equilibrium shift using aspirator, molecular weight of carbon dioxide, mobility of ions

In the first year, 'combustion of iron' experiment and interview was performed to analyze students' perception types on the problem-emerging situation. The methods of data collection were interview and participation observation to look into students' thought and behaviors within the framework of phenomenological approach, and the data analysis progressed from a phenomenological analytics (Pattern, 2000).

Interview materials were collected, students' verbal interactions during activities were recorded and the observation notes were written in. The interview was started explaining experiment sequences. Moreover, to investigate reliability of the experimental results, two questions "what was the expected results at first?" and "if you acquired unexpected results, would you think that your results would be reliable?" were conducted. And, to investigate reliability of experiment methods, the interview included two questions "did you trust the given experiment methods?" and "did you correct the given experiment methods?" progressed. Interview was semi-structured. During the interview, to exclude prejudice, subjects' opinions were concentrated and recorded directly to be useful in analyzing the results.

The interview materials repeatedly were transcribed and compared with recorded students' verbal interactions. Two materials went through continuous interpretation, and the observation notes were also referred during the research analysis.

Typological results, through these processes, presented three types in terms of reliability of experiment results and methods. The analysis results of science education experts as well as researchers were made a comparative study for reliability.

In the second year, ten problem-solving experiments were conducted for one semester. Researchers' role was mainly an observer and also an inducer to lead free atmosphere. Researcher just answered the questions about experiment apparatus, materials, and given procedures, that means they did not concern any further.

The questionnaires performed at the beginning and the end of the semester consisted of descriptive questions; "if you gained unexpected results though followed the given experiment methods, what do you think was the cause of the results?" Students' answers were analyzed 'the reliability of experiment methods' and 'the reliability of experiment results', and the results were checked through interview. To secure validity of analysis of interview and survey questions, one professor of chemistry and three chemistry secondary teachers helped to examine and correct the contents.

Ⅲ. Results and Discussion

In this study, perception types of unexpected results in problem-solving experiment are classified.

1. The perception types on unexpected results

To measure reliability of experiment results and methods, two questions "if you acquired unexpected results, would you think that your results would be reliable?" and "did you trust the given experiment methods?" were conducted.

The pupils' responses divided into 'trustworthy' and 'untrustworthy' on the unexpected results. The students who answered 'untrustworthy' thought they were unfamiliar with an experimental execution, so they recognized strongly on experimenter's mistakes.

On the contrary, the other students were subdivided 2 classes of reliability of the given experiment methods. The first group who trust the methods was well aware of "they put confidence in their results and methods, there were commonly differences between expected results and performed results, and the place between theoretical and practical outcomes was existing as a general tendency." The second group presented the perception about the importance reading between lines in the given methods, namely they responded that the given methods could not cover everything in detail.

Figure 1 presented the students' perception on the reliability of experiment results and methods, and each type's feature was like this. The change of number of the students in each type, before and after the experiment, presented in "2. the influence of problem-solving inquiry experiment on the change of recognition."

1) The gap between theory and practice

The students who felt the unexpected results based on the gap between theoretical and practical outcomes believed in their results and the given methods. 9 Students in this group mentioned that the causes of the differences were 'the defect of experiment apparatus' and/or 'human limit.' The following sentences show students' response examples about the causes of 'the gap between theory and practice.'

> The experiment was done by human, so less accurate. And there were variable interruptions like minute temperature change or pressure variation during experiment...

> I had assumed the accuracy of experiment apparatus, but actually it was often not. At first, I did not recognize that all pipettes showed difference in volume according to their own properties in carrying out the experiment in high school.

These types of students had little tendency of reinterpreting irregular instances gained by experiment and presented resistance of preconception's corrections or changes (Lin, 2007). Besides, they admitted the differences between practical and theoretical outcomes, so they were not likely to explain special reasons about those causes.

2) Missing factors between lines

After acquiring unexpected results, the students who tried to get better results by improving the experiment methods trusted in results obtained, but did not trust in methods. The inclination of improving experiment methods was divided into two classes – the one was an activity of searching for ignored processes in manuals and adding them, and the other activity was to improve by including their own ideas.

The latter class students thought unexpected results were one of the challenges of enabling to give the change, and more they believed their results, so the given experiment methods could be changed by intent.

> I did the experiment in modifying the condition. In the previous experiment, as you saw I tried to use a hair dryer to promote chemical reaction, so the result was not slightly matched up... The manual said put it in acetic acid by about 2 minutes, but I did it too shortly...

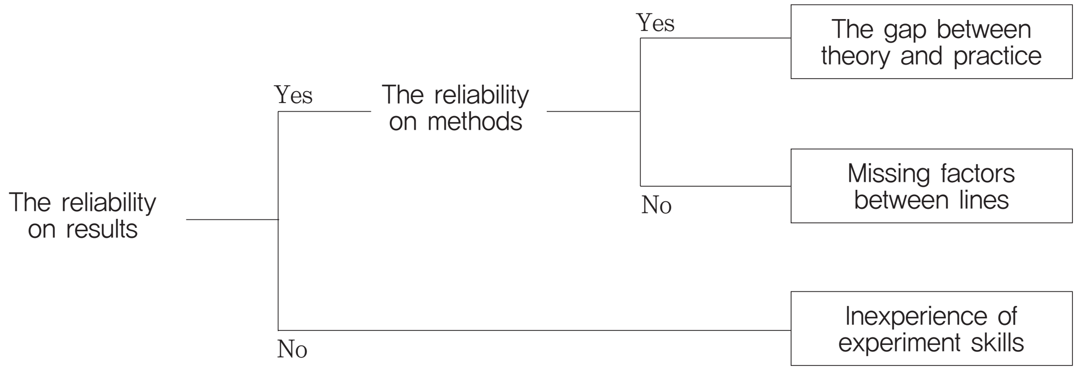


Fig. 1 *The perception types about unexpected results*

These participants checked whether experimental results were reproduced; in that case, they started to search for new variables. Then, they planned the experiment to confirm new variables and proceed step by verifying them.

The students who found overlooked parts in the experiment manual and improved them thought unexpected results came from unrealized procedures. These students showed to checking directions for performing experiment or finding omitting procedures.

> There were commonly the factors which raised the differences in experiment procedures. So, I had to consider about that but, I did not. I should have treated these factors. But you know, when you repeated experimental procedures several times, you usually could realized those factors. Later, when I executed experimental procedures considering these factors, I might acquire accurate results.

These students are different from students who tried to find new variables, in that they caught overlooked procedures within the manual. Furthermore, in the respect of inquiring the cause of unexpected results, these students are different from students as inexperience of experiment skills.

3) Inexperience of experiment skills

The students who did not trust their results thought the results came from their mistakes or inexperience. Actually, most of the students believed, regardless of previous experiment experience more or less, their first result arose from mistakes. Next are the students' response examples about the causes of 'Inexperience of experiment skills.'

> It must be my simple mistakes like measuring a beaker's weight wrongly or thinking length differently... Miscalculation would be possible thing. There would be something wrong. I had to retry until I could find something wrong.

> At first, I was unfamiliar with the experiments, so I felt difficulties of reading the gradation and made errors frequently. But later, I became used to the experiments more and more, so the results were quite accurate.

As was stated above, these students did not find the causes of unexpected results, merely they regarded the results came from the experimenters' mistakes. Moreover, they considered that reexecuting an experiment could bring expected results so mentioned the importance of unconditional repetitions to acquire better results.

2. The effect of problem-solving experiment on perception types' change

After performing problem-solving experiment for one semester, comparative analysis of the change of students' perception types was carried out, and each type's features were looked into. The students' perception types change based on analysis of question, "if you gained unexpected results though you followed the given experiment procedures, what do you think was the cause of the results?" presented in Figure 2.

The number of the students who recognized the causes as 'the gap between theory and practice' declined from 9 to 2 at the end of the semester. And, the number of the students who thought 'inexperience of experiment skills' slightly increased from 6 to 8. On the other hand, the number of type, 'missing factor between lines' sharply rose from 3 to 8 at the same time. Student's perception on 'the gap between theory and practice' was considerably decreased, but the number of the students who realized as 'missing factor between lines' was quite increased. Here are detailed explanations on these changes.

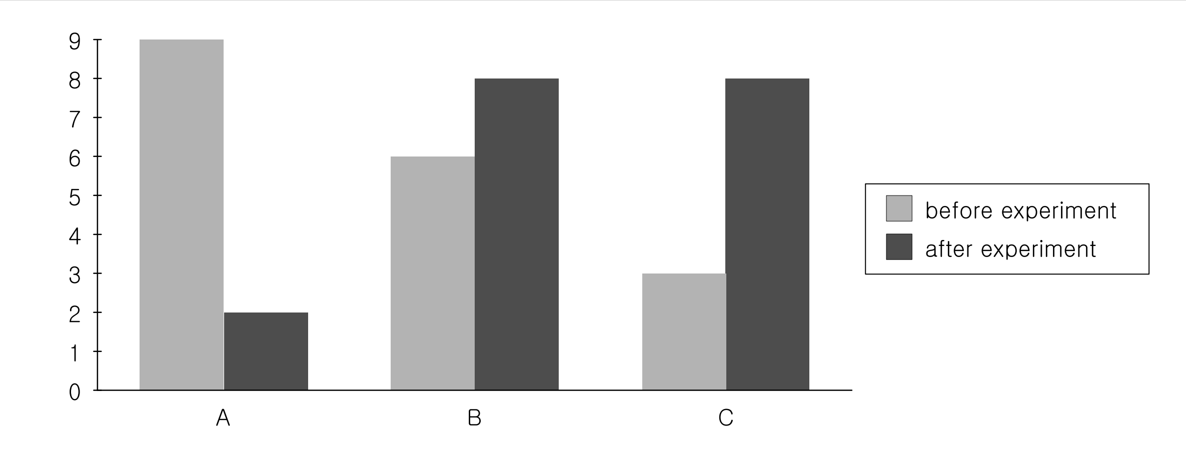
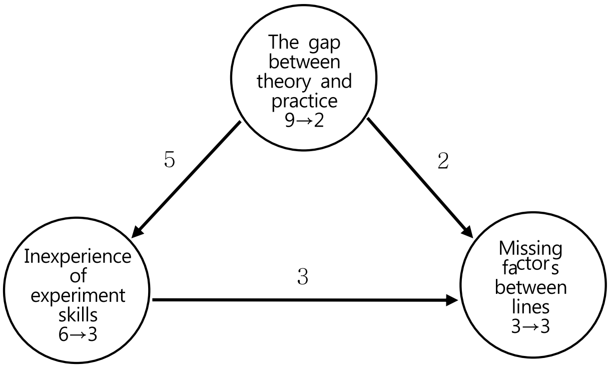


Fig. 2 *The students' perception types change on unexpected results (A; The gap between theory and practice, B; Missing factors between lines, C; Inexperience of experiment skills)*



Among 9 students in 'the gap between theory and practice', only 2 students still thought the causes as 'the difference between theory and practice', 5 students changed their opinions into 'inexperience of experiment skills' and 2 students changed their opinions into 'missing factor between lines.' Among 6 students in 'inexperience of experiment skills', 3 students held their thought as 'inexperience of experiment skills', and the other changed into 'missing factor between lines.' But, notable point was that all 3 students who recognized them as 'missing factor between lines' unceasingly insisted same causes.

Below are some presented responses of the students who marked the change as 'the difference between theory and practice' into as 'inexperience of experiment skills' or 'missing factor between lines' at the end of the semester.

> To 'inexperience of experiment skills'
> At the beginning; the theory was always accurate, but, in experiment, external factors and human mistakes should not be ignored. We cannot proceed the experiments as it is like machines.
> At the end; after carrying out the experiment, the strange results came from experimenters' inexperience like unclean beakers.

> To 'missing factors between lines'
> At the beginning; the most important uncertainty was the place we lived was not ideal.
> At the end; owing to wrong experiment methods, the results were naturally different. In this case, we need to review this manual, find hidden (not written in manual) causes, and then retry to perform the experiment.

Below are presented some responses of students who changed 'inexperience of experiment skills' into 'missing factors between lines.'

> At the beginning; I made a lot of mistakes in quantity, and ignored experiment conditions. At the end; I thought unconsidered variables and changed experiment methods.

These results revealed the tendency of the students' change. The stream of change was from 'the difference between theory and practice' to 'inexperience of experiment skills' and from 'inexperience of experiment skills' to 'missing factors between lines.' A part of students turned 'the difference between theory and practice' into 'missing factors between lines.' To put it briefly, the direction to change was 'the difference between theory and practice' to 'inexperience of experiment skills' and to 'missing factors between lines.' There were no students who had tendency to counter direction.

In problem-solving experiments, students faced problem-emerging situations and admitted plenty of space for improvement. These recognition have students draw idea and read between lines. Because problem-solving experiments make students follow these process, problem-solving experiments, in our opinion, act on student's perception.

Ⅳ. Conclusion

This research was reflected on scientists' research process and so focused on unexpected results which would lead scientific discovery. When unexpected results were emerged to the students, students' perception types and change of the types were analyzed through interview and questionnaires.

Above all, the students' perception types on unexpected results in experiment were classified as 'the gap between theory and practice,' 'inexperience of experiment skill,' and 'missing factors between lines.' After applying the problem-solving experiments for one semester, the perception change was observed and the direction of the change from 'the gap between theory and practice' to 'inexperience of experiment skills' and to 'missing factors between lines.'

Characteristics of three perception types indicated that the perception types on 'the gap between theory and practice' and 'inexperience of experiment skill' were influenced on previous experience about the experiment. Added to this, the students usually think they have lower ability to conduct the experiments accurately.

However, according to above results, students' past experience could not establish the recognition for inquiring new variables on unexpected results.

Second, before doing problem-solving experiment, most of the students considered unexpected results as 'the gap between theory and practice' or 'inexperience of experiment skill.' But after experiencing that experiment for one semester, the perception, 'the gap between theory and practice' was dropped and the desire for inquiring new factors, which is 'missing factors between lines', was increased. Added to this, each features of change showed the students included the type 'inexperience of experiment skill' were less not likely to change rather than the students included 'the gap between theory and practice.'

Students' past experiment until science curriculum in high school did not provide them with the opportunity of experiencing new inquiry from unexpected results to lead scientific discovery. Despite of occurrence of unexpected results, there are clear limitations of the connection toward new inquiry. The students who acquired these unexpected results need to examine their reproducibility of results by redoing an experiment. If they check the reproducibility, the students should find overlooked processes in manual and improve by including their ideas in inquiry. In this process, they can gain new results. Therefore, the activities which enable to recognize unexpected results positively and lead to start new inquiry for the students are required. There is a limitation, if the students just follow a given experiment process in the problem-solving experiment. So, to solve the limitation, creative problem-solving power is needed. To achieve this, one of the strategies is problem-solving experiment, and this alternative can help the students to think with new variables and recognize to pursue innovative experiment methods. The teachers should teach the students to interest unexpected results, and to solve the problem, raise a thinking ability to able to create ideas.

Reference

Bodner, G. M. & Herron, J. D. (2002). Problem-solving in Chemistry. In Gilbert, J. K. & Jong, O. D. & Justi, R. & Treagust, D. F. & Driel J. V. (Eds.) Chemical Education: Towards research-based practice (pp. 235-266). Kluwer Academic Publishers.

Brush, S. G. (1974). Should the history of science be rated X? Science, 183, 1164-1172.

Dunbar, K. (1993). Concept discovery in a scientific domain. Cognitive Science Society, 17, 397-434.

Dunbar, K. (2000). How scientists think in the real world: implications for science education. *Journal of Applied Developmental Psychology*, 21(1), 49-58.

Germann, P. J., Aram, R. A., & Burke, G. (1996). Identifying patterns and relationships among the responses of seventh-grade students to the science process skills of designing experiments. *Journal of Research in Science Teaching*, 33(1), 79-99.

Hofstein, A. (2004). The laboratory in chemistry education; thirty years of experience with developments, implementation, and research. Chemistry Education: Research and Practice, 5(3), 247-264.

Hofstein A., & Lunetta, V. N. (2004). The laboratory in science education: foundations for the twenty-first century, *Science Education*, 88. 28-54.

Lee, E.-K. & Kang, S.-J. (2008). The Effect of SWH application on problem-solving type inquiry modules through student-student verbal interactions. *Journal of the Korean Association for Science Education*, 28(2), 130-138.

Lim, H.-Y. & Kang, S.-J. (2009). Undergraduates' response pattern on the problem-solving-type general chemistry laboratory. *Journal of the Korean association for Science Education*, 29(2), 193-202.

Kim, H.-K. & Song, J.-W. (2003). Middle school students' ideas about the purposes of laboratory work. *Journal of the Korean Association for Science Education*, 23(3), 254-264.

Kim, Y.-S. (2010). The Comprehension of process of the creative idea generation produced in a process of the idea-creative type inquiry, Unpublished master thesis of Korea National University of Education, pp15-18.

Kim, Y.-S. & Yang, I.-H. & Park, G.-S. (2006). The analysis of quantity of science experiment lessons in university. *The Research of Secondary Education*, 54(1), 79-94.

Leonard, W. H. (1983). An Experimental study of a BSCS-style laboratory approach for university general biology. *Journal of Research in Science Teaching*, 20(9), 807-813.

Lin, J. Y. (2007). Responses to anomalous data obtained from repeatable experiments in the laboratory. *Journal of Research in Science Teaching*, 44(3), 506-528.

Noh, T.-H., Lim, H.-Y. & Kang, S.-J. (2000). Types of students' responses to anomalous data. *Journal of the Korean Association for Science Education*, 20(2), 288-296.

Park, J., Jang, K.-A. & Kim, I. (2009). An analysis of the actual processes of physicists' research and the implications for teaching scientific inquiry in school, *Research in Science Education*, 39(1), 111-129.

Patton, M. Q. (2000). Qualitative research and evaluation methods (3rd ed.). London: Sage Publications, pp. 104-110, 113-115, 482-487, 497–499.

Shepardson, D. P. (1997). The nature of student thinking in life science laboratories. School Science and Mathematics, 97(10), 37–44.

Soldatova, L. N. & King, R. D. (2006). An ontology of scientific experiments, *Journal of the Royal Society Interface*. 3(11): 795 803.

Tamir, P. (1997). How are the laboratories used? *Journal of Research in Science Teaching*, 14(3), 311–316.

Tobin, K. (1990). Research on science laboratory activities. School Science and Mathematics, 90(5), 403–418.

Yang, I.-H., Jeong, J-S., Kwon, Y.-J., Jeong, J.-W., Heo, M. & Oh, C.-H. (2006). An intensive interview study on the process of scientists' science knowledge generation. *Journal of the Korean Association for Science Education*, 26(1), 88–98.

Yi, H.-J. & Kang, S.-J. (2005). Reformation and application of an introductory chemistry laboratory at the university for teacher education. *Journal of the Korean Association for Science Education*, 25(3), 346–352.