Asia-pacific Journal of Education Management Research
Vol.2, No.1 (2017) pp.37-42
http://dx.doi.org/10.21742/ajemr.2017.2.1.07

Pre-service Teachers' Understanding of Science Practices for Inquiry–oriented Chemistry Labs

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Abstract

The purpose of this study was to observe and analyze how pre-service elementary teachers perform free-style inquiry-oriented chemistry experiment. The study investigated motivations and circumstances of selecting experiment topics and looked at how pre-service teachers handled unexpected mistakes and results. Then, the study explored what epistemic goals and considerations might affect the ways in which pre-service teachers practiced chemistry labs.

Keywords: *Pre-service elementary teacher education, Science practice, Chemistry Labs*

1. Introduction

During the last two decades, what it means to teach and learn science has shifted significantly. Historically, the focus has been on the delivery of science content, but the new goal of science education is aimed at helping students become scientifically literate citizens who are able to act in ways seen as scientific [3][4][5]. To achieve this purpose, engaging in science "practices" is centered as a way to construct and evaluate scientific knowledge [1][4].

In Korea, the emphasis on "doing freestyle inquiry" is consistent with the notion of science practices. Through engagement of science practices, students learn not only related science content knowledge but also epistemic criteria of constructing and critiquing scientific knowledge (i.e., what counts as scientific knowledge). These science practices include asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, engaging in argument from evidence and obtaining evaluating, and communicating information. From this practice-centered perspective, students are expected to develop or refine a scientific question that can be answered through conducting science experiments. They should be able to create models that explain and predict natural phenomena, and should be able to evaluate the merits and limitations of models. Students are expected to design scientific investigations that will collect relevant data used to answer their questions, identify, control and analyze experimental variables. Of course, they have to analyze and interpret these collected data and find patterns and relationships. They also need to be able to use various representations such as graphs, tables and other drawings. Through these processes, they are also expected to engage in argumentation, and produce sound scientific explanation. Yet, despite the emphasis of freestyle inquiry in national curriculum standards, in reality, science classes are not conducted in this way because of the lack of time, experiences, related knowledge required for science teachers, and the burden of preparing

Article history:
Received (January 10, 2017), Review Result (March 11, 2017), Accepted (April 30, 2017)

Print ISSN: 2207-5380, eISSN: 2207-290X AJEMR

students for college entrance tests. In particular, most elementary pre-service teachers have not taken any advanced science classes during high school [2]. As a result, they lack experience with designing and conducting freestyle science experiments. Considering this condition, we designed two-step experiments that consisted of a basic, guided experiment and a freestyle experiment related to the basic, guided experiment. In this way, we expected pre-service elementary teachers to acquire more knowledge of and confidence with designing and conducting freestyle inquiry-oriented experiments.

The aim of this study was to observe and analyze how pre-service elementary teachers perform freestyle inquiry-oriented chemistry experiments. The study was guided by three research questions:

1) What are the motivations and circumstances pre-service teachers consider when deciding on experiment topics?
2) How do pre-service elementary teachers change and update their experiments when they do not go as planned?
3) What epistemic goals and considerations do pre-service elementary teachers hold when they engage in these experiments?

2. Methods

Qualitative design was used for this 15-week study for the purpose of gaining an in-depth understanding of how pre-service teachers plan and conduct their experiments, as well as how they respond to any difficulties encountered. Twenty-three pre-service elementary teachers (freshmen and sophomore), who were enrolled in a basic chemistry and experiments course, participated in this study. Of the teachers, 13 had never taken any chemistry courses in high school, eight had taken only Chemistry I, and two had taken an advanced chemistry class. To organize a group, one or two pre-service teachers who had taken any chemistry course were included in every group to ensure the knowledge level of each group was similar. The teachers participated in a two hour experiment class once a week, for 15 weeks. Among these classes, this study was focused on six weeks of the course, during which three topics were covered that captured the pre-service teachers' interest and enthusiasm. The three topics included combustion, acid-base indicators, and solubility of gases. One of the reasons for the higher interest seemed to be that content related to these topics is covered in elementary science classes. As described earlier, experiments based on fundamental chemistry concepts consist of two steps. Students first performed a basic, guided, manual-based experiment to make sure they understood basic chemistry concepts and to acquire essential processing skills. Next, they were asked to design and conduct a freestyle experiment. The pre-service teachers conducted a flame test for understanding the concept of combustion, a cabbage indicator for understanding acid-base, and an ammonia fountain experiment for understanding the solubility of gases. After conducting these guided, basic experiments, they were given a week to design a freestyle open-ended experiments. These teachers were also asked to include phone-recorded video clips and pictures in their reports, to increase the accuracy of records and as a supplement to note-taking.

Main data sources included the field notes the first author took, experiment reports, discussion between the pre-service teachers and the second author conducted both in real-time and via email. The first author observed and took notes for every experiment, but did not interrupt. A research team consisting of a science education professor, a doctoral student with more than 20 years' experience of teaching chemistry, and a master's student, discussed what the data meant and came to consensus through ongoing discussion. For answering RQ1, motivations and circumstances to consider were collected from the field notes, experiment reports, and emails. These data were categorized and coded using an inductive, top-down free coding method. For answering RQ2, teachers' responses to unexpected situations were divided into three categories including 1) perceiving and defining problems; 2) developing solutions; and 3) specific strategies and behaviors useful for making solutions. For answering RQ3, the ways in which pre-service teachers set up epistemic goals and presented various epistemic solutions depended on whether the experiments were successful. Thus, the features they showed were analyzed into two categories: the success of the first attempt and the failure of the first attempt.

3. Findings and discussion

In contrast to the initial expectations that the pre-service teachers would generate their experiments from scratch, they chose their topics from existing books and Internet blogs, in most cases, with slight modifications. They listed four important considerations when selecting experiments: 1) interesting enough for elementary children to be used for classes in the future; 2) an experiment consisting of a simple procedure 3) demonstration of the same phenomenon with different scientific principles; and 4) easy to prepare materials. The pre-service teachers tended to avoid experiments that took too much time or required complicated procedures. They preferred to conduct experiments for which success was guaranteed, as well as those with visible effects such as dramatic changes of color or status. They seemed to be conflicted in that they had the idea that overly simple experiments might hinder them from receiving higher grades, but, at the same time, they thought the failure of the experiment might have a negative impact on their grades.

When they met unexpected, unsuccessful situations, most pre-service teachers decided to conduct the experiments again. Mostly, however, the teachers repeated the same methods without any consideration of revision. For example, when they conducted a carbon dioxide fountain experiment, the lid ruptured. While it was due to higher pressure as carbon dioxide was generated, the pre-service teachers did not attempt to figure out the reason of the lid exploded. Instead, they compared the procedure described from the Internet, with what they have done. Then, they repeated the same experiment again. Students were less interested in how and why their results would happen, and how it might relate to other scientific phenomena and theories. As for the only exception, a group of pre-service teachers attempted to review their existing ammonia fountain experiment. They developed a new method and devised new equipment for Heron's fountain [Figure 1]. They rescheduled another experiment using their free time, after regular class hours. While they determined that a shorter and thinner tube might increase the inner pressure from the fountain, they were not able to find replacement materials for the existing tube.

The epistemic goal of scientists is to construct new scientific knowledge. The purpose of conducting freestyle experiments is not much different in this regard. However, the findings from this study indicate that the epistemic goal of the pre-service teachers was to ensure the success of their designed experiments rather than to encourage inquiry and take the risk of conducting unsuccessful experiments. Most pre-service teachers tended to think the reason for an unsuccessful experiment was due either to simple mistakes or misunderstanding of the background content knowledge. In other words, they seemed to simply believe the information in textbooks or blogs was correct. Consequently, they put little effort into trying to fix or improve any of the experiments. Rivalry or evaluation of knowledge among various opinions rarely occurred within and between groups. As Berlnd and her colleagues pointed out, there was, at least, some variation in the degree to which students would produce, evaluate and connect their science practices with other specific explanation and phenomenon. In our cases, the same kinds of products (such as making fountains) and results (same colors observed) have made students to believe that similar scientific theories exist, without taking other possible scientific knowledge or explanation into consideration. When one views knowledge produced in a connection to other specific phenomenon, one tends to use the scientific explanation to generalize such ideas [6][7]. Alternatively, one may take their knowledge produced as the part of science ideas generalized. However, the pre-service teachers were less interested in making this kind of connection between theories and phenomena observed. Instead, they were primarily satisfied with the logical coherence within the experiment itself. For example, when they found that phenolphthalein turned into purple after they found bubbles inside of the beaker, linked to a tube, they concluded that they were not able to collect enough amount of carbon dioxide because of leaking carbon dioxide. None wondered about why and how the lid exploded in the first time anymore. While interpretation of data and synthesizing their results from a theory-generation perspective is a critical condition for conducting a free-style inquiry oriented experiment course [8][9] it would be difficult for these pre-service teachers to perform these practices voluntarily unless their goal of conducting experiment change from replicating knowledge to generate it.

The pre-service teachers participating in this study seemed to be satisfied with any idea coming up as long as the experiments were easy enough to conduct and interesting. Thus, argumentation and discussion rarely happened during the planning stage of experiments. Rather, in the case that their first attempt was unsuccessful, discussions centered on changing the topic or repeating the same experiment. These pre service teachers viewed the results produced through their experiment as a duplicate of existing ideas that others instruct them. Consequently, the purpose of conducting experiment for students was to enhance understanding of related concepts or was to confirm knowledge known already. The epistemic standards from this perspective, thus, would be the degree of accuracy or the alignment with knowledge existing.

In this study, the features of conducting freestyle experiments, including motivations for topic selection and attitudes toward handling unsuccessful experiments, appeared to be influenced by pre-service teachers' epistemic goals and considerations for their science classes. For example, they seemed to believe the main goal of performing any experiment is to enhance related conceptual knowledge. Based on this belief, they seemed to think an unsuccessful experiment is derived from a lack of related knowledge, which impeded them from fixing or adjusting the experimental design, procedure, or equipment. As for future research, more analysis through in-depth interviews that reveal the relation between students' epistemic understanding and ways to design and conduct a freestyle, open-ended experiment is necessary. The hope is that this will contribute to the improvement of pre-service teachers' performance in creating freestyle experiments and their epistemic understanding of science.

Figure 1. (a) Initial experiment equipment used (b) New equipment for Heron's fountain

Devised new equipment for Heron's fountain

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