Chapter 12
Stories of Teaching Hypothesis-Verification Process in Elementary Science Classrooms

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12.1 Introduction

There have been various forms and approaches of inquiry-based teaching to enhance children's scientific mind and skills since scientific inquiry is recognized as one of the main goals in science education (AAAS 1989; Crawford 2007; NRC 1996, 2000). Among various approaches of inquiry teaching, hypothesis-based inquiry has been recognized as an effective way to develop children's scientific reasoning and problem solving in science teaching. Studies suggested that hypothesis construction and evidence-based reasoning can be taught to young children (Jeong et al. 2007; Joung 2008; Tytler and Peterson 2003), yet there are pedagogical concerns in its implementation in classrooms. First, even though hypothesis is the central part of investigative process, the definition and role of hypothesis have not been examined thoroughly among science educators and teacher practitioners (Wenham 1993); thus, it has been difficult to agree on its practice and outcomes accordingly. Second, there has not been sufficient discussion on pedagogical framework and practice of hypothesis-based inquiry teaching in classroom settings. In this regard, this study attempts to raise some pedagogical issues of hypothesis-based inquiry in preservice teachers' classroom practice. To do so, we start to examine the nature of hypothesis and verification.

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12.1.1 The Nature of Hypothesis Verification

Hypothesis is the principle intellectual technique of investigation in the history of scientific development (Hanson 1958; Lawson 1995). For instance, Kepler's explanation of the features of Mars' orbital and Galileo's discovery on constancy of gravitational acceleration are the examples of scientific discoveries conducted by generating hypothesis. These discoveries were made neither by just interpreting mathematically the necessary consequence of hypothesis, that is, deductive inference, nor by extracting mechanically a common factor from collected observations, that is, inductive inference. They were discovered by generating hypothesis based on abductive inference that goes beyond the information in prior data (Hanson 1958). Scientists construct hypotheses based on the phenomena they observe and carry out numerous experiments to test their hypotheses throughout the history of science, for example, Loffler and Roux's hypothesis and test on diphtheria and the therapeutic use of antiserum resulted in a significant development of germ theory in medical science history (Beveridge 1961). A good hypothesis indeed brings out an important contribution to scientific development. A good hypothesis, at first, is *a* hypothesis, but eventually transformed into a theory through evidence afforded by subsequent investigation (Lawson 2003). If the hypothesis holds right explanation for all situations, it can be evaluated as a theory or law if sufficiently profound (Beveridge 1961).

There have also been wrong hypotheses which have led fruitful scientific development in the history. For example, in Western Australia, H. W. Bennet made a hypothesis that neurodisease of swayback (sheep) was due to lead intoxication and carried out his tests with ammonium chloride which is the antidote to lead. However, his test results made him doubt about his initial ideas. The disease was not always cured by ammonium chloride. Thus, he constructed another hypothesis that the disease might be due to deficiency of some mineral which was present in the first batch of ammonium chloride, not ammonium chloride itself. Bennet soon found out that the neurodisease was due to deficiency of copper, a deficiency never previously known to animal's disease. This case indicates that scientific development can also result from a false hypothesis and the importance of critical analysis of test results and reexamination of hypotheses.

The structure of hypothesis as conjecture of phenomena and experimental design as method of dealing with evidential phenomena must be suitable for each other's end. In other words, the following tests must be purposefully designed and practiced to verify the explanations. Without the connection between hypothesis and tests, hypotheses cannot be proved and experiments become disconnected with no outcomes or benefits to accepting or refuting the hypotheses. In the understanding of the purpose of experiments, there requires critical and open-minded approaches to our hypothesis in data interpretation. Beveridge (1961) explicitly mentioned that "we must strive to judge the data objectively and modify or discard it as soon as contrary evidence is brought to lift. Vigilance is needed to prevent our observations and interpretations being biased in favour of the hypothesis" (p. 52). That is, we need to design experiments and methods based on presupposition that our hypothesis is true and yet, collect and interpret data without overinclination to the hypothesis. The data interpretation and analysis must require critical, open-minded approach.

With the importance of hypothesis-verification process in science communities, hypothesis-based approach has been practiced in science classrooms, especially in the area of problem solving, scientific explanation, and argumentation. Hypothesis plays a central role in posing and articulating the aspiration and direction of problems (Lawson 1995, 2003; Klahr and Dunbar 1988), in collecting and analyzing data systematically (Hempel 1966; Wenham 1993), and in explaining why problematic phenomena happen (Hanson 1958; Millar 1989). Therefore, hypothesis plays a central role in learning problem-solving process as well (Lawson 1995). To implement this method effectively in classrooms, it is crucial for teachers to understand how to construct hypothesis and how to test and analyze test results in investigative inquiry. However, the understanding of hypothesis has been perplexing and challenging among science educators with multiple aspects of assumption, tentative explanation, tentative cause, tentative law, and prediction (Jeong and Kwon 2006; Yoon et al. in press). For example, hypothesis and prediction are used occasionally for the same purpose without understanding the role of hypothesis and prediction, that is, to answer to the questions "why it happens?" or "what will happen?". Especially in elementary levels, prediction was suggested as hypothesis considering the level of students' conceptual knowledge and capacity of problem solving (Gilbert and Matthews 1986). Because of the multiple understanding of hypothesis, the approach of hypothesis-based inquiry has also been practiced in various formats and directions.

In this work, we take the view of hypothesis as a tentative explanation. Hypothesis as tentative/suggested explanation or solution is the one most widely used in science education (Park 2006; Wenham 1993). It is a tentative explanation when we encounter an unusual situation and try to make sense of the unusualness (Peirce 1998). In other words, hypothesis is a kind of tentative answer to the question "why a present phenomenon happens?" (Lawson 1995; Salmon 1998). Based on tentative explanation or solution, students predict results and determine what to observe based on variables. They collect data and interpret and make a conclusion tightening the original explanation and data collected. Without this tentative explanation or solution, students' hypotheses in science classrooms turned out to be a simple prediction on what will happen in the end. Lawson (1995) explained that "prediction" is a thing that is posed from hypothesis by deduction, is to be compared with the result of experiment, and then is to verify the hypothesis by inductive process. Thus, hypothesis is different from prediction. It requires a certain process of logical thinking to presuppose reasons of prediction. We in this study, attempt to differentiate hypothesis from simple prediction and highlight that without understanding the nature of hypothesis, hypothesis-based inquiry cannot sufficiently develop scientific reasoning and evidence-oriented mind theoretically expected in hypothesis-verification approach. To claim this notion, we will discuss some episodes of teaching scenes later on in this chapter.

To discuss the challenges of the nature of hypothesis and verification practiced in classroom teaching, this study examines how preservice teachers implement this approach in elementary science classrooms and what difficulties and conflicts emerge during their practice. Observing their teaching practice and reflecting together with the preservice teachers, we attempt to understand the challenges of hypothesis-based inquiry teaching in classroom practice and ways of helping preservice teachers with understanding hypothesis-based inquiry.

12.2 Research Method

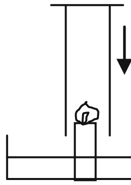
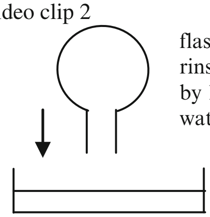
12.2.1 Research Context

To understand the dynamics of teaching hypothesis-verification process in elementary science classrooms, we invited fourth-year university students (preservice teachers) in elementary science methods course in this study. Sixteen preservice teachers were asked to design inquiry-based science lessons, teach them to elementary students, and reflect their lessons during 15 weeks of their course work. From the first to sixth week of the course, the preservice teachers were engaged in exploring teaching strategies to help children with problem-solving process based on hypothesis making, designing experiments and controlling variables, collecting data, and making a conclusion. In the seventh to ninth week, the preservice teachers were divided into three groups and collaboratively designed one inquiry lesson per group. They chose lesson topics that they thought were the most suitable and interesting for children's inquiry learning. All three groups developed an inquiry lesson based on hypothesis-verification process. In Lesson 1 "snowman's coat", elementary students needed to figure out how they could keep ice cream (popsicles) from melting longer. The students observed their popsicles for 10 min in three conditions: leaving it as it is, fanning it, and wrapping it with cloth. Lesson 2 was "paper spinner and hoop plane." The students were asked to make their own hypotheses of what makes the objects fly longer. Lesson 3 was "candle flame and rising water." Students were asked to find out under what condition and why water level goes up higher after candle flame goes off inside of cylinder. Children came up with the number or length of candles as variables in their hypothesis testing. Among three lessons, we explain the details of lesson 3 below (see Table 12.1). Because stories from lesson 3 distinctively explain the issues of hypothesis-based inquiry teaching than the other two lessons[1] (see Table 12.1).

To carry out more effective lessons for children, the preservice teachers practiced inquiry activities beforehand to develop inquiry teaching strategies and reduce any anticipated errors. From the tenth to thirteenth week, they taught their lessons to 18 elementary students in a special interest group in science. The class was a mixed group of students in grades 4, 5, and 6. The preservice teachers taught their lessons

[1] We have discussed lessons 1 and 2 more in detail to discuss the difficulties of inquiry teaching in our other work (Yoon et al., in press). In this chapter, we particularly focus on the issues of hypothesis-verification process in the cases of lesson 3.

Table 12.1 The sequence of lesson 3, "*the candle flame and rising water*"

Process	Activities	Video clips in the lesson
Introduction	A video clip of burning candle and covered by a cylindrical glass Children observe and discuss why the water is rising after the candle went off	Video clip 1 
Hypothesis making	Children in four groups make hypothesis on under what condition water will go inside more Children presented their hypothesis to the whole class. They explained their ideas based on oxygen consumption	
Testing	Children design their experiments with variables and constants based on their hypothesis and conduct test	
Data interpretation	Children collect data and examine if their hypothesis was right. They make conclusions	
Presentation	Children present their results and conclusion to the whole class	
Ending video	Teacher shows another video clip of rising water inside flask, but with no candle flame involved Teacher explains that the main reason of water level rising was heat (temperature change), not oxygen consumption	Video clip 2 

as team once a week. The class last 1 h and 30 min each time. After the classroom teaching, the preservice teachers returned to the university and had discussion on their experiences of preparing and teaching their lessons for the last 2 weeks (14th–15th week).

12.2.2 Data Collection and Analysis

In order to understand problems and difficulties of hypothesis-based teaching, we videotaped the preservice teachers' classroom teaching and group discussion to closely look into their decision making and actions. The data from group discussion was used to understand their actions in depth. In data analysis, we modified and employed the process of open coding, axial coding, and selective coding originally suggested by Glaser and Strauss (Flick 2006), which we found useful to search for integrated themes and relationships among research data. This helped us understand the phenomena of hypothesis-verification teaching practice more coherently and thematically. Open coding was done individually. Through the preservice teachers' reflection in group discussion, we could also understand why their actions occurred in certain ways during lessons. Themes from the group discussion were cross-checked with the video data of their teaching.

For axial coding, we gathered to discuss our individual interpretation, themes, and concerns related to the data. During this step, we discussed what would be the similarities and differences in our interpretation and thematization to find out integrated, coherent themes and concerns of hypothesis-based teaching. We watched the video clips to discuss the different views and modified our themes.

For selective coding, we selected some episodes from lesson 3, and discussions which we agreed distinctively exhibited the concerns and difficulties of teaching hypothesis-based inquiry. Then, we discussed the details of preservice teachers' experiences, decision-making scenes, and actions in the episodes to reexamine the themes and the contexts of the episodes. This process of coding by comparing and cross-checking the data from different sources helped us understand the relationships of their decision making and action which we could not recognize from one source of data. By following those steps, we could analyze and conclude the integrated themes of the difficulties and concerns of hypothesis-based inquiry in classroom teaching.

12.3 Research Findings

In this study, we found several pedagogical difficulties in teaching hypothesis-based inquiry in elementary science classrooms. We attempt to highlight the difficulties in three stages of the teaching of scientific investigation: (1) hypothesis construction, (2) experimental design and test, and (3) data interpretation. In hypothesis construction, we discuss the lack of understanding hypothesis. In the stage of experimental design and test, we argue that it is important to understand the roles of testing in teachers' practice. Lastly, we discuss that teachers need to develop their pedagogical skills to encourage children's data interpretation and analysis based on experimental results.

12.3.1 Lack of Understanding of Hypothesis

Hypotheses require tentative and testable explanation to given problems in order to develop an investigative process. That is, constructing a hypothesis can be the beginning of good investigative inquiry. However, the preservice teachers seemed to have difficulties to understand what would be suitable forms of hypothesis to lead hypothesis-verification process more fruitful and scientific. During the lessons, they asked children to predict the result of given problems as hypothesis making. Children wrote down what would happen in the end without thinking or explaining why it would happen. Their hypothesis making did not include a tentative explanation to the given problem. In this case, children's hypothesis is only a simple prediction, not a hypothesis. For instance, in the first lesson (snowman's coat) led by the first group of preservice teachers, children were asked to predict in which way they could keep ice bars the longest without melting among three options (fanning, leaving with no interruption, and wrapping with cloth). Children made a hypothesis such as "when we fan on it, it will melt the fastest." In the second lesson (paper spinner and hoop plane), children were asked to fill in the blank on the sentence, "when wings are _______, paper sinners will fall down slowly." Among four groups of children, three groups made a hypothesis that "the longer wings are, the more slowly paper spinners will fall down." And one group said, "when the wings have an appropriate length, the spinner will fall down slowly" without further explanation on what appropriate length meant.

In lesson 3 (candle flame and rising water), children's hypothesis making seemed a bit more appropriate in terms of including tentative explanation. The third group of preservice teachers guided children to come up with possible reasons for their prediction on candle and rising water. Here are the details of children's hypothesis making in lesson 3 (Episode #1).

12.3.1.1 Episode #1

Two preservice teachers, Tae and Kang, were team-teaching in this lesson. Tae taught the first half and Kang taught the second half. The two other preservice teachers in this group were helping children's group work. In the beginning of the lesson, Tae showed a video clip of a burning candle on a petri dish half-filled with water. Then later, the candle was covered with a measuring cylinder. Children observed the candle flame go off and the water level inside the cylinder rise. Tae attempted to guide children's discussion on their observation. He asked:

Classroom dialogue #1

Tae (teacher): Why do you think the water level has gone up inside the cylinder? Could you write down your thinking and present it to the class?

(A few minutes later, Tae asked what students wrote.)

Student group 1: We thought it is because the air disappears because of the candle flame and the water was replacing the space of the air.

Tae: Ok, good work. What about next group?

Student group 2: It is because oxygen will be consumed and there will be empty space. The water went into the cylinder to fill the space.

Tae: Ok, next group, are you ready? All right. Tell us your thought.

Student group 3: There is difference of air pressure inside the cylinder. And, oxygen disappears and the water is sucked in to replace the space.

[Omission]

Student group 4: Oxygen disappears so the water goes in to fill the space.

Tae: Ok, good work, guys. Now I am going to ask you to think of how you can make the level of water higher inside the cylinder.

Later, Tae asked children to make hypotheses, suggesting the sentence of "when_____, the water level goes up higher because_____." Three groups of students said that "the more candles are inside, the higher water level will be because they will consume more oxygen." One group (student group 3) presented a different condition. They suggested that "the longer the candles are, the more water will go inside because carbon dioxide is heavier than the air and can extinguish the flame. In this case, the flames can stay longer." But their explanation was also based on the idea of oxygen consumption inside the cylinder, as shown in the Classroom dialogue #1.

After the lesson, the researcher and the preservice teacher have a time for reflective discussion on the lesson. During reflective discussion, the preservice teachers showed their views of hypothesis that is different with the researcher's, as shown in the dialogue below.

Reflective discussion #1

Researcher: You asked them to write a hypothesis? And what else?
Shin: Before that (making hypothesis), we asked them to think of reasons and write them down on their individual worksheet.
Researcher: So it was writing a hypothesis?
Jin: No, before making hypothesis.
Shin: Through the activity sheet, they could understand the problem….
Jin: And the reason why the water level rises.

This episode exhibits a few difficulties in the preservice teachers' teaching of hypothesis making. First, the preservice teachers who taught this lesson understood a prediction as hypothesis similarly to preservice teachers in the 1essons 1 and 2. Although the suggested format of hypothesis making consisted of two parts (the first part is for "prediction," the second part is for "the reason of the prediction," that is, "hypothesis"), the preservice teachers regarded the first part, "prediction," as hypothesis (see Reflective discussion dialogue #1).

Second, this view of hypothesis in the preservice teachers' understandings caused their misunderstanding of the purpose of a "test". The purpose of a test in the process of hypothesis verification is to test the hypothesis, i.e., tentative explanation. The preservice teachers, however, did not examine whether the experiments designed by the children is suitable for testing the hypothesis, "oxygen consumption" (see Classroom dialogue #1 and Episode #2 for more details). Rather, they just tried to observe the results of experiments. That is to say, they attempted to test just a prediction, "the more candles are inside, the higher water level will be." Actually, it is not easy to test directly the hypothesis "oxygen consumption" by measuring the amount of oxygen inside the cylinder, because there were not sufficient equipment or materials in the classrooms. The preservice teachers could have considered if there was any available method to test the hypothesis, not the prediction itself, and have guided children to design an experiment to test their hypothesis. The preservice teachers in the episode, however, did not seem to realize these points. They did not understand the role of test in hypothesis-verification process. We will discuss this in details in the following section.

12.3.2 Understanding the Roles of Test

To justify a hypothesis, there requires a fair test. To attain the fairness of test is to plan and control the variables and constants which could verify the tentatively argued explanation in the hypothesis. In this way, hypothesis could be reexamined and improved. For example, if the suggested hypothesis is "when there are more candles, the water level goes up higher because they consume more oxygen," then a test needs to be designed to verify "more oxygen consumption and higher water level." And yet, the preservice teachers did not have sufficient understandings of the role of test in hypothesis-verification process and the connection between hypothesis and test. The lack of these understandings led children's work not fruitful. In lesson #3, children's test with the different numbers of candles could prove that their prediction (the more candle, the higher water level) turned out to be right, however, could not verify their explanation (because of oxygen consumption). Here are more details of the notion.

12.3.2.1 Episode #2

After children made their hypothesis such as "the more candles, the higher water level because of oxygen consumption" in the student groups 1, 2, and 4 and "the longer candles, the higher water level, because carbon dioxide is heavier than the air" in the student group 3, the teacher asked children to deign experiments to test their hypotheses. Children set up their tests based on variables and constants and started testing their hypothesis out. In their testing, what students actually observed was that the water level went higher when there were more candles. In other words, in their approach, the test seemingly confirmed that their hypothesis was true. Children concluded the experimental result showed that their hypothesis was right. While children were writing up the results, Kang took over the next part of the lesson from Tae. Then she asked children to present their findings and conclusion. After three groups presented, a boy from the student group 4 is presenting their group work.

Classroom dialogue #2

Kang: Let's hear about the last group's conclusion.

Boy 1: We thought that when there are more candles, the more water will go inside because when the candles are burning, carbon dioxide will come out and the density of carbon dioxide is bigger than oxygen and any other gas inside the cylinder. So there will be some empty space and the water will be sucked in to replace the space.

Boy 2: Therefore, we tried to test cases with 1, 2, 3, and 4 candles. We made the same the amount of water [in the petri dish], the size of cylinder, the length of the candles, and the time we cover the cylinder…Errr, we could not do the case of 4 candles. The level of water was 5 cm for 1 candle, 6 cm for 2 candles, 7 cm for 3 candles. We did not have time for 4 candles.

The result of student group 3 also showed their hypothesis (strictly speaking, prediction) was right. After the last group finished their presentation, Kang realized the process was ended with something that her group did not anticipate. Kang realized that children were getting wrong ideas that the water level goes up mainly because oxygen is consumed and water is replacing the space of oxygen. She attempted to teach children the “correct” reason for the phenomenon and concluded the session with the following remarks.

Classroom dialogue #2.1

Kang: To sum up your hypothesis and conclusion, most of you thought that the candles are using oxygen and the water goes inside to replace the empty space. So you designed your test and carried it out. However, think about what you observe on the video in the beginning. If it is because of oxygen consumption, the candle flame is continuously consuming oxygen, the water would go up gradually. However, on the video, you saw the water was suddenly going up very high after the flame was off.

A boy: Because of heat…

Kang: Then, we thought it was related to oxygen… let’s watch one video clip to think about other reason.

She showed children a video clip (video clip 2 in Table 12.1) that her group had prepared beforehand. The video clip showed a demonstration of which a teacher rinses a round flask with hot water and puts it upside down on a petri dish half-filled with water. There was neither candle nor flame involved in the demonstration, so there should be no activities of combustion and oxygen consumption. By showing this video clip, the preservice teachers attempted to explain the relationship between water rising and heat (temperature). The lesson was ended without further discussion on children’s experiment and conclusion by showing the video clip (refer to Table 12.1).

In hypothesis-making, a tentative explanation is built by abductive inference based on one’s experiences, observation, scientific knowledge, and so on and a prediction can be led deductively from this tentative explanation (Hanson 1958; Lawson 1995). Afterward, a test will prove the prediction right or wrong and thus verify the tentative explanation. In the case of lesson 3, since the prediction did not stem deductively from the tentative explanation, it could not play a significant role to verify hypothesis through test. It also seemed that the preservice teachers did not recognize what children’s tests would prove was not only the prediction part (the more candle, the higher water level) but also the explanation part (oxygen consumption) which is essential to verification of hypothesis. We could argue that if the preservice teachers had understood this role of test, they could have rethought children’s making hypothesis and designing test. But it was not the case. Without any teachers’ guide on hypothesis making or planning for test, children carried out their test and attempted to oververify their hypothesis based on test results (Episode #2). The collected data and test results were not sufficient to prove whether the reason for the rising level of water was oxygen consumption or something else (e.g., heat or air temperature). The independent variable (the numbers of candles) and dependant variable (water levels) are enough to prove the prediction, but unsatisfactory to explain the reason (the amount of oxygen).

In hypothesis-verification process, designing valid tests is a critical process to verify hypothesis. The variables on tests need to be designed to examine tentative explanations that investigators presuppose. Even though the preservice teachers in lesson 3 encouraged children to come up with temporary explanations, there was no deep understanding in which test also needed to take into consideration the explanation, not only prediction. They did not realize that the variables in children's experimental design, for example, the number or length of candles, could not justify the hypothesis as a whole (prediction and explanation). And yet, we do not argue that it is meaningless to have hypotheses which cannot be justified by test or constructed based on wrong concepts in the first place. Through thorough test design and discussion process, the hypothesis will be revised or eventually proved wrong, and it could lead further scientific thinking. However, without appropriate pedagogical scaffolding, hypothesis-verification inquiry process would be unfruitful and might result in perplexing results of knowledge and inquiry skills.

12.3.3 Skills of Data Analysis and Discussion

In hypothesis-verification process, data collection and interpretation are critical for the evidence of scientific explanation. This study showed how difficult it is for preservice teachers to help children analyze or interpret experimental data on site. In actual classroom teaching, the data collected and interpreted by children were rather unpredictable and, thus, the preservice teachers seemed not prepared to scaffold the process of analysis and conclusion based on test results. In all three lessons, data interpretation and analysis were not taken thoroughly to discuss the relationships among test results, conclusion, and scientific knowledge. The following episode shows that there was not much learning of data analysis.

12.3.3.1 Episode # 3

Children in the student group 3 made a hypothesis that the longer candles were, the more water goes in, because when the candle is longer, it will take more time that CO_2 will cover the candle frame. They continued to explain that it helps the candles consume more O_2 so there will be more empty space. They also thought that the density of CO_2 is denser than O_2; therefore, even if CO_2 is produced from combustion, there will still be some empty space. Then they set up a test and collected their data with different lengths of candles. Their results showed that when the length of candle was 5 cm, 8 cm, 11 cm, 14 cm, and 17 cm, the level of water was 6.1 cm, 6.5 cm, 5.2 cm, 5.4 cm, and 5.2 cm, respectively. The children presented their result by using a table and graph.

Classroom dialogue #3

Boy 2: To conclude, differently from our hypothesis, when the length of candle is not too long, not too short, but proper, the level of water is the highest. That [the proper length of candle] was 8 centimeters.

Kang: So you thought in the beginning that when the candle was longer, water would go up more. Why did you think that way?
Boy 1: errr… ummmm….
Boy 2: Because if the candle is longer, it will take longer time that carbon dioxide reaches the flame, um…and the water also goes up gradually and…so, it will take longer time to reach the flame.
Kang: So you thought the short candle will go off early because carbon dioxide reaches it first so only little water goes in [to the cylinder], is it?
Boy 2: Yes.
Kang: But in your results, it says that longer candles did not have more water in, ya? The 8 cm candle got the highest water level?
Boy 2: Yes…
Kang: Okay, thanks. Please, group 4 [next group], could you come out and present your work?

The teacher moved on to the next step without any discussion on this notion.

In this episode, the children's result was worth a further discussion. The preservice teacher could have encouraged the children to examine why their hypothesis was not true or if they would want to change or revise their hypothesis or test setting. However, just confirming the results without any further discussion or questions, the preservice teacher moved onto next step to get other group to present their results. This notion of lack of data interpretation appeared in all three lessons that the preservice teachers conducted in this study. They did not show much time and effort in interpreting and analyzing data together with children. If the preservice teachers had asked children to discuss why the results were different from what they expected, it could have generated and developed more reasoning skills and scientific minds to look into the relationships between the phenomena and knowledge. For instance, if the preservice teacher asked the children "why were the results different from what you expected?" the children might explore various reasons and activities such as the following: "because the difference between density of CO_2 and O_2 has not critical influence dissimilarly to our expectation. It needs to reconsider our hypothesis," "because there might be measuring error or noise effects that we did not expect. To do confirm these ones, we need other experiment settings, for example, with bigger/smaller cylinder. In addition, we need to have more articulated measuring tools and skills," and so on. There were not enough awareness and scaffolding of the teachable moment to fulfill the aspects of investigative inquiry process and developing children's learning and knowing.

12.4 Discussion

Based on the findings, we highlight the difficulties of teaching hypothesis-based inquiry in the dimensions of the nature of hypothesis, role of test, and skills of data analysis and interpretation. First, there needs to be a sufficient understanding of the nature of hypothesis to conduct a hypothesis-verification inquiry effectively. If there is one sentence, one observation, or one single inference about a single concrete object with no testable explanation in hypothesis making, the statement is not sufficient to become a hypothesis (Quinn and George 1975). And testability of a hypothesis depends on whether the hypothesis has observable predictions that can verify the hypothesis, not on whether the prediction is just observed. In this study, because the preservice teachers did not fully understand the distinction between simple prediction and hypothesis (see the Episode #1), the process of hypothesis verification became a simple observation on the test result, not being able to test and understand scientific explanation in the phenomena (see the Episode #2). To enhance higher level of thinking and reasoning, teachers need to understand the nature of hypothesis in their teaching.

Second, there needs to be more understanding of the role of test in hypothesis-verification process. Studies explain that hypothesis leads us to decide what to be observed (as well as how, when, and where) and which variables are likely to be significant to justify hypotheses (e.g., Wenham 1993). This draws our attention to the coherent link between tentative explanation and prediction as well as hypothesis and following test. In this case, the fairness of test is to take account into not only the skills of controlling variables fairly but also the connection of hypothesis and test. Without the thoughtful thinking process between them, the process of hypothesis verification became disjointed work with irrelevant data and explanation to certain phenomena. Test is not only a straightforward observation on what is happening during experiment. This also means that variables and constants in the test need to take into account the explanation suggested in the hypothesis. If we intend to enhance the value of fair test, the variables and constants need to be controlled in the connection to what needs to be observed and tested. For instance, children's test on candle flame and rising water could verify the part of prediction (the more candle, the higher water level) without taking into consideration the explanation (because of the oxygen consumption). In this case, the fairness of test needs to be reexamined to test a hypothesis as a whole.

Third, teachers also need to know how to scaffold children's data analysis and interpretation to make conclusions. Data collecting and interpretation based on evidence are the essential components of scientific investigation and reasoning; however, the connected examination between primary data and the statement of results has been often ignored in the process of scientific reasoning (Kanari and Millar 2004). In this study, children simply presented the summary of their findings and teachers accepted children's presentation as analysis and conclusion without further discussion. In the end, the children in the study miss an opportunity to experience the essential components of scientific investigation. In the discussion of data interpretation and conclusion, teachers also need to understand the dynamics of children's communication, as fundamental nature of scientific knowledge development to guide children's scientific attitudes (Scott et al. 2006) and the value of sharing plural accounts as collectives in groups to enhance the abilities of data analysis, conclusion, and scientific argumentation (Duschl and Osborne 2002; Kelly et al. 2001). We believe that the preservice teachers' understanding of hypothesis-verification process and pedagogical decision making and skills will be improved over time, yet it is only possible through the reiteration and critical reflection on their practice of hypothesis-based inquiry teaching in classrooms. There needs to be more integrated approach to understand the dynamics of teachers' understanding and practice of hypothesis-based inquiry teaching in further research.

12.5 Concluding Remarks

Hypothesis-verification process is beneficial to enhance children's scientific minds and problem-solving skills. Being engaged in the process, children learn how to make hypothesis, design experiment test their hypothesis, and reach conclusion. However, to make the process fruitful and valid, more systemic and disciplined instruction is required to develop children's reasoning and skills of evidence-based scientific investigation. The process of hypothesis verification is not simply "predicting what" but "explaining why" on given problems. Teachers' understanding and decision making on how to intervene or guide children's work would be challenging without sufficient understandings of the nature of hypothesis and the roles of test. To aim for the development of higher level of scientific thinking and problem-solving skills, this study suggested that teachers' appropriate pedagogical actions based on their understandings of hypothesis, test, and analysis would be essential. And yet, this study still remains some issues of the readiness of children's cognitive ability and the levels of scientific-thinking skills in elementary classrooms. Distinguishing simple prediction from hypothesis in elementary levels might be argued as an unnecessary challenge for teachers as well as children; however, we believe that this argument needs to be rethought for elementary science education to evoke children to seek for evidence to claim for their ideas.

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