Measuring the Earth's Size Using the Sun's Altitude and The Responses

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ABSTRACT

This study was created to resolve the problems embedded in the formal measuring experiments to determine the earth's size in the current curriculum, to develop an updated measuring experiment to determine the earth's size and to establish its effect.

For this study, pre-service elementary teachers, who had attempted the experiment of measuring the size of the earth when they were in middle school, performed the experiments in the existing national curriculum, and their responses, collected through in-depth interviews, were examined.

To begin with, the pre-service elementary teachers conducted the experiment of measuring the earth size and they recorded the problems while performing it. At the end, an in-depth interview was administered. Based on the problems, an updated measuring experiment to determine the earth's size was suggested to be applied to the same contents and be analyzed through the in-depth interviews.

Common themes which were mutually categorized and analyzed by the two researchers were obtained based on the records produced while conducting the experiment and the in-depth interview data.

The teachers mentioned that the experiments for measuring the size of the earth in the current curriculum gave rise to difficulties in measuring precisely the angles between the string and the post. Also, there has been a scientific contradiction that solar altitudes were increased in a high latitude region, instead of decreased. For this reason, an alternative method has been developed to measure the earth's size using the distance and the solar altitude difference of two places. The teachers all agreed that by using the updated measuring experiment, they can acquire more precise measurements and it is easier, faster and consequently more effective than the existing methods.

Through the results of this study, I suggest that the newly developed experiment by the researchers can overhaul the problems of the current experiments and it can be an effective alternative to the current experiment.

Key words : updated measuring experiments to determine the earth's size, solar altitudes

Ⅰ. Introduction

The objects of study in earth science have included developing facts such as the scale of space and time, impossibility of approaching, impossibility of control and complexity which differ from science disciplines (Kim, 2002). It can be not only what is invisible from the beginning and end due to forming after a long time such as stratigraphic formation but also it can be suitable for first hand observation rather than second hand, like the investigation of the substance inside the earth. Also, the object of study from other fields in science focuses on a small scale, whereas the one in earth science is too enormous to do an experiment in the lab (Lee & Kwon, 2010). That being so, modeling and operating something plays a significant role in earth science (Engelhardt & Zimmermann, 1982; Giere, 1988, 1999) because it focuses on natural phenomenon which is related to real life and difficult to experience and impossible to be experimented with control (Gobert & Clement, 1999). Thus, diverse modeling in earth science class is commonly used to make students easily

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comprehend the knowledge of earth science.

Experiments related to the measurement of the earth in the second grade of middle school are also designed to measure it in a secondhand way. This experiment is based on Eratosthenes's which was considered innovative in earth science among historical cases in science development. This experiment is meaningful in measuring the size of the earth. However, the more outstanding point is they measured it by using altitude difference indicating his remarkably scientific inquiry.

This experiment of Eratosthenes caused serious problems for the students and teachers in school introducing the concept of earth size. The problem is because the current textbook emphasizes only the concept of alternate angles and the distance between Syene and Alexandria. In fact, students and teachers had difficulty grasping the experiment of measuring the earth's size (Woo, 2007).

So, I determined the problems of the method of measuring earth size in this study by observing pre-service elementary teachers doing the experiment of measuring the earth's size shown in the current textbook. I developed a new experimental method to measure the size of the earth, applied it to pre-service elementary teachers and examined the effects.

To do this, the specific questions of this study are as follows:

First, what are the problems of the experiment for measuring the earth's size presented in the current textbook?

Second, how to create an updated experimental method for measuring the earth's size to compensate for the problem?

Third, what are the pre-service elementary teachers' responses to the updated experimental method for measuring the earth's size?

Ⅱ. Research Method

1. Participants

Thirty pre-service elementary teachers voluntarily participated in this research. They are attending an intensive science class and took the natural sciences track in high school. They took earth science class of measuring the earth's size and clearly recognized the purpose of this research.

2. Data Collection

First of all, the experiment process in textbook A (Yoo & etc, 2010) as a representative within 8 different textbooks in the current grade 2 middle school textbooks was presented and the experiments were conducted in groups (Figure 1). The reason I selected textbook A from 8 other choices was they all have similar materials and processes, so I didn't need to see any differences among them.

I made them take notes whenever they felt difficulty in carrying out the experiment. After it was done, we had in-depth interviews and it was recorded and transcribed.

Based on the data, I developed an updated experimental method to solve the problems, and had the pre-service elementary teachers do this experiment. With this updated experiment, they also made notes of their thoughts about the content and the method of the experiment. I conducted the same interview with them following the updated experiment.

3. Data Analysis

I created the protocol of current textbook problems and the effect of the updated experiment on the basis of notes participants made and in-depth interviews. I developed the updated experiment related to measuring the earth's size, examined the participants' responses and categorized them according to cross-tabulations.

Ⅲ. Research Results

1. The problem of measuring the earth's size presented from the current textbook

1) The difficulties in the experimental process

Pre-service elementary teachers raised their voices about the difficulties in the middle of the experiment and the process in the textbook as follows:

Materials Globe, two small sticks, ruler, protractor, thread, tape

To experiment

① Place a globe where the sun shines. Then locate the two small sticks right on the globe so that they have the same longitude but have the different latitude.
② Make sure that the one of the two sticks casts no shadow and the other stick casts the shadow (we will only measure the angle where the second stick casts shadow).
③ Measure the length between the two sticks.
④ Using the protractor, measure the angle from the tip of the stick to the shadow.

Conclusion

① Compile the data on the following table.
② Define the relationship between the center angle and the angle found from the second stick,
③ Let's set an equation using the theology, ***360°: the center angle = circumference of the globe: the length between the two sticks.***
④ Calculate the circumference of the globe.
⑤ What is the presumption that is needed in order to find the size of the earth?

Fig. 1. An experiment for measuring the size of the Earth in textbook A

First, they had trouble measuring the exact shadow in the experimental methods in which they measured the shadow of the sucker-based stick.

Student: When I measured the shadow of the stick, the end of the shadow was not clear so I had difficulty measuring the exact length of the shadow.

Student : There was a huge error between the actual experiment and the textbook's because the boundary of the shadow was not clear so we measured it with a rough guess.

Second, they had to do the experiment of creating the shadow from one stick and no shadow from the other stick by adjusting the globe. They complained about adjusting the globe.

Student : It is difficult to find the exact spot where the shadow disappears in order not to create the shadow of one stick. We just did the experiment under the condition of shortest shadow of the stick.

Third, they had trouble fixing the two sticks at the same longitude and measuring the distance between the two sticks by using a measuring tape.

Student : The globe is round and the stick is too big compared to the globe so it was so difficult to fix the two sticks at the same longitude. It is next to impossible to fix the two sticks at same longitude so there was an error in the actual value.

Student : It was difficult to measure the distance between the two sticks by using the measuring tape. The

globe is round and it was tricky to measure the surface of the globe with the measuring tape.

Fourth, they had difficulty connecting between the tip of one stick and the shadow by the thread and measuring the angle between the thread and the stick by the protractor.

Student : The shadow of the stick was exactly refracted. I doubt if it is possible to get the actual value when it comes to measuring the angle between the tip of the shadow and the stick connected by the thread. Also, we can't measure the exact angle by the protractor because we have to turn it over in measuring the angle.

2) Experiment Process Contradiction

Pre-service elementary teachers said that there was a contradiction between science theory and the actual experiment in the midst of the experiment presented from the current textbook. Comparing the two sticks, there wasn't a shadow of the stick located at the high latitude whereas there was a shadow of the stick at the low latitude. This is a complete contradiction. They responded as follows:

Student : As far as I know, the stick at the high latitude must have a shadow because the altitude of the sun is low. But when I conducted this experiment, the shadow at the high latitude disappeared and the shadow at the low one showed up. I adjusted many times but I failed and just measured the experiment as it was. It was far-fetched from the scientific knowledge that I know (Figure 2).

Student : This method might give students a misconception about the altitude of the sun. When you conduct this experiment, the shadow at the high latitude doesn't appear. This enables students to think wrongly that the high altitude of the sun is a high altitude because the high altitude doesn't have a shadow.

There were pre-service elementary teachers explaining the causes with their analysis.

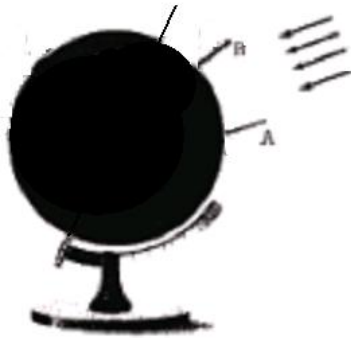

Fig. 2. Feature showing B solar altitude is larger than A solar altitude.

Student : In fact, we supposed that the sunray hit the earth vertically at the surface of the earth but the sunray in this experiment goes down to the globe so it makes the shadow of the stick show up.

Student : This experiment brings out a result contradicted to the scientific concept in the first figure which is shown from your side. When the sunray hit the earth from the side, the experiment may turn out well. Although you conduct the experiment with a flashlight, it can't be replaced for a sunray due to refraction and this is not the best way because many problems occur.

2. A new compensating experimental method to measure the size of the earth

A method of measuring the size of the Earth in current textbook is using an alternate angle between two places by attaching two sticks on a globe, which makes one stick have a shadow and the other don't. This method is hard to find the two spots on the globe, to measure the alternate angle and it makes a lot of errors. Also, this method is not to measure actual size of the Earth but to find out the size of the globe.

I created an updated experimental method in order to compensate for the problem that current textbooks have in measuring the size of the earth and make it easier and more accurate. This method is to use the distance and altitude between two different spots with the measurement in reality during the class or the altitude data of the sun from the Korean Astronomy & Space Institute (Figure 3). This method is like this.

First, I measured an altitude data of the Sun in a region from an web site named the Korean Astronomy & Space Institute (http://www.kasi.re.kr/). Then, I also measured an altitude of the Sun in other region from the same web site. Third, I found out a direct distance between two regions through the Internet. Fourth, I made a proportional expression with altitude difference between two regions and measured the circumference of the Earth.

The proportional expression to measure the circumference of the Earth is as follows:

Altitude difference of the sun between A and B : 360° = Distance difference between A and B : The circumference of the Earth

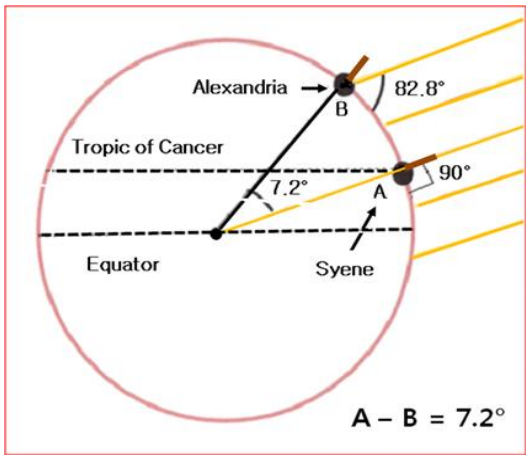

Fig. 3. An updated method of measuring the Earth's size using the solar altitude.

3. Pre-service elementary teachers' responses to the updated experimental method in measuring the size of the earth

Their responses are as follows:

First, they said this updated method was a better way to get the exact value rather than the current textbooks' methods.

Student : This updated method introduced the concept of the altitude of the sun the current textbook didn't take into account in order to enhance the accuracy of the estimation. Also, this drew the accurate experiment result which used the accurate data from specialized sites compared to other experiment methods. It was very beneficial to get a more accurate value in schooling from an experimental principle angle.

Second, they said this method was faster and easier in doing experiment and getting an accurate value than the existing one.

Student : This method is an easy one when you use a proportional expression with the altitude and distance of the sun between two regions. It was more convenient to do the experiment because the complicated experiment process in the current textbook was simplified.

Student : The current textbooks have a large probability of error during the experimental process from measuring the shadow, angle, and distance of two sticks. Also, the existing method in current textbooks included unnecessary processes. However this updated method has a simple experimental process and is able to get an accurate value. It is like killing two birds with one stone.

Student : This updated method was easier and more simple in respect to the experimental process and method. Also, it was easier to understand why we have to do this.

Third, they said the updated one was more interesting and fun.

Student : When I did the existing experiment method, it was too complicated and I sometimes was lost with what to do during the experiment. Even though I understood the value of the experiment, I lost interest due to many errors. However, the updated one was very interesting because it was easy to get an accurate value only with the altitude of the sun. Also, it was amazing and interesting that you can measure the size of the earth with the altitude of the sun.

Fourth, they said it was more effective rather than

the existing method in that they can measure an value with simple process.

Student : When I heard about the updated way, I thought 'This way may work out'. I thought that this updated method would be more effective and efficient because it is done faster if you can get an accurate value of the distance between two regions and altitude of the sun from specialized online sites and solve and compensate the *process via setting up an expression, getting an accurate value of the circumference of the earth.*

Student : I think this updated method is more efficient for both teachers and students in the way that you can measure the altitude of the sun only with one stick and protractor.

Fifth, they said it could resolve the problems the existing method had.

Student : In the existing method it was easy to make a huge error. The shadow of the stick at the higher latitude didn't show up. Whereas the problem was the shadow of the stick at the lower latitude appeared. This means that the contradiction happens like the altitude of the sun is high at the high altitude. However, this updated method simply resolved this problem.

Sixth, they said it was very interesting to use a computer, keeping up with the times.

Student : It is a very good way to go online in measuring the size of the earth because computers are widespread and dynamic these days. It is able to keep with the times.

Ⅳ. Conclusion

This study is aimed to examine the problem of measuring the size of the earth displayed in the current middle school textbook and to investigate the pre-service elementary teachers' responses towards a revised experiment.

First off, pre-service elementary teachers complained the difficulty of the experimental process and its contradiction as problems of measuring the size of the earth in the existing textbook's experiment.

The difficulty during the experimental process is to measure the shadow and make a shadow of one stick by adjusting the globe. It is easy to make an experimental error while measuring the angle between the thread and the stick on the globe.

The contradiction happened between the reality and the experiment. In the reality, the higher the altitude is, the longer the shadow is. However in the experimental situation, the higher the altitude is, the shorter the shadow is depending on the position of the sun; a shadow at the lower altitude had showed up.

For this very reason, I introduced an updated experimental method to pre-service elementary teachers and I looked thoroughly into their responses towards the updated method. The pre-service elementary teachers have reported that the updated method was easier, faster and more convenient. Also, using the updated method, it only took a very short time to produce an accurate measurement value compared to the existing experiment. In addition, the teachers mentioned it was a method to compensate for the problem the existing textbook experiment had.

I strongly believe that the updated measuring method that I have created will remove the problems that happened in the current textbook.

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