

# Analysis of Experiments for 'Measuring the size of Earth in 8th Science Textbooks

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**Abstract:** The purpose of this study is to analyze methods for measuring the size of the Earth, put forth in 6 different Korean 8th grade science textbooks. The research questions are as follows: 1) Do they adequately map out the experiments for measuring the size of the earth by using the concept of the sun's altitude? 2) Do they reduce the size of the sun like as the Earth is similarly downsized to the globe? 3) Do they suggest the precise experimental conditions for selecting two equal longitudinal spots for measuring the size of the earth? 4) Do they design adequate experiments for exact measurement? 5) Do they offer a proportional expression for seeking the size of globe which is easily understood by students? 6) Do they develop experiments to measure actual size of the earth?

Four graduate students and one researcher took part in this study. All conditions were unanimously agreed upon by the participants. The results are as follows. First, one publishing company must include the concept of the sun's altitude to accurately measure the size of the Earth. However, some textbooks fail to mention this. As such, the concept of the sun's altitude must be introduced to accurately measure the size of the Earth. Second, a reduced size globe is used as the actual earth so; the sun should be factored in with a reduced light value. Third, you have to lay a stress on two points at the same longitude. In other words, a shadow located at the same longitude from two randomly selected points. Most textbooks mention two points at the same longitude but two of them design the experiment with a shadow at the same longitude. Fourth, we need a method to precisely measure the angle between a stick and its shadow. The angle between the stick and the tip of its shadow is the sun's altitude difference. Fifth, we need to present more specific proportional expressions for calculating the size of the globe. Only 3 out of the 6 texts employed a proportional expression. Sixth, we need to calculate the size of the earth by accurately presenting the scale of the globe to attain the goal of the experiment. Two of the texts analyzed, designed the experiment for the purpose of calculating the size of the globe. Three of the texts designed their experiments to calculate the radius of globe which is not even relevant to the purpose of experiment.

**Key words:** Eratosthenes' measurement of the Earth, the sun's altitude, the sun's altitude difference, alternate angles

## I . Introduction

It is very significant to precisely define terms and cohesively utilize them in a science textbook which covers basic natural phenomena. However, schools use different textbooks, therefore preventing any inconsistency in science education. Also we can often find wrongly and ambiguously defined explanations. Also, the inconsistency in figures and experiments used to understand some terms may hinder scientific thought. Kwon & Kim (1993) mentioned that the internal factors which affect a student's formation of pre-concepts and scientific thought in constructive learning is a student's cognitive traits and logical inference.

External influences are the teacher, textbook and ambiguity of language. Since the textbooks mentioned above play a crucial role as a media between teacher and learner, the contents, figures and experiments in the text should be described easily. Not only had to be easily understood by teacher and students but also to accurately present scientific concepts.

Historically, one of the most important discoveries in the field of 'Earth Science' is Eratosthenes measurement of the Earth. This was otherwise known as 'the revolutionary incident'. Eratosthenes displayed an incredible knack for scientific thought by measuring the size of the earth by using the sun's altitude difference. His measurement is often used when

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researchers are exploring new concepts in science. In fact, the 7th curriculum in the 8th grade textbook presents the fact that the earth is round and we can measure its size by using a globe. So, Eratosthenes' measurement of the earth's size was introduced for students to improve their measurement abilities in 8th grade science class.

However, teachers and students alike have said that they had trouble understanding the experiment related to the measurement of earth's size. This means we have a procedural problem in science education. Concept-related statements and experimental supplements are desperately needed. Earth science concepts are comprised of macroscopic things, meaning we usually feel limited to learn these concepts in the classroom or a laboratory. Considering that like most earth science concepts, the measurement of the earth's size is largely performed in a classroom context. We need specific research on the subject how we should deal with the teaching of earth's measurement.

So far, the following research has been released domestically and in foreign journals, concept statements, figures and tables in textbooks which affect pre-conceptions in science learning and which might create and strengthen misconceptions as well. (Driver et al., 1985; Kook, 2003; Oh, 2003; Choi & Cho, 1987), research and analysis on the lack of systematic coherence of the science curriculum, textbook, experimental observation statements and experiment-related problems such as factoring in the wind (Chae & Jung, 2007). Research on the contents, pictures and experimental analysis (e.g. adiabatic change) of six types of high school, Earth Science textbooks (Chae, 2008). However, research related to measuring the size of the earth has not been conducted. Thus, the purpose of this research is to analyze and compare the contents, pictures and experiments of Korean, 8th grade science textbooks which cover the measurement of earth's size. Also we should suggest cohesive and efficient contents

for textbooks. For this, researchers chose several agendas through analysis of documents such as 'mapping out the experiment of measuring the size of the earth by using the concept of sun's altitude, 'Do they reduce the size of the sun as the earth is downsized to the globe for calculations? Do they select two equal longitudinal spots for measuring the size of the earth? Do they design an experiment for exact measurement? Do they offer a proper proportional expression to seek the size of globe which is easy for students to understand? Do they develop the experiment to measure the actual size of the earth?'

## II. Method

### 1. Target textbook

The subjects are 6 of the middle school science textbooks used in the 8<sup>th</sup> grade science curriculum such as (A) Kyohak publishing company (Choi, *et al.*, 2002); (B) Keumsung publishing company (Lee, *et al.*, 2002); (C) Blackbox publishing company (Kim, *et al.*, 2002); (D) Daeildose publishing company (Jung, *et al.*, 2002); (E) Jihak publishing company (Lee, *et al.*, 2002); (F) Didimdol publishing company (Kim, *et al.*, 2002). The researcher selected the six most easily attainable texts, out of the eight which are currently being used throughout Korea.

### 2. Collecting materials and analyzing

This research was conducted by a professor who majored in science education and four graduate students, who are elementary school teachers with careers ranging from 5–10 years. The graduate students had enrolled in and completed my course on "Earth Science" prior to conducting this research. As the primary researcher, the researcher directed my graduate students to investigate the content and conduct the experiments related to measuring the size of the earth as they are currently laid out in middle

school texts. After conducting the earth measurements as per the texts, researchers reported to me on the problems and difficulties encountered. The criteria of the analysis were 'Did the text map out the experiment of measuring the size of the earth using the concept of the sun's altitude? Did the text's method reduce the size of the sun as the size of the earth was reduced to that of a globe? Did the text require precise experimental conditions by selecting two equal longitudinal spots when measuring the size of the earth? Did the text design an experiment for exact measurement? Did they offer a proper, proportional expression to seek the size of the globe which is helpful in making the experiment easily understandable? Did they develop an experiment to measure actual size of the earth?'

The primary researcher and graduate students presented and discussed all problems which were encountered. Discussion proceeded in a manner of free and open presentation of ideas. Comparative discussions took place three times and lasted at least 3 hours each time. In the process of discussion, the researchers came up with an agreeable analysis criteria such as the experimental agenda suggested above. All researchers reached a consensus. In addition, the researchers compared what was reflected in the research to notes, including discussion contents and then rechecked and revise them in order to increase the validity of the data.

### III. Result

#### 1. Textbook A

① Textbook A does not refer to sun's altitude difference. However, the experiment only carried out the process of calculating the alternate angles by using a proportional expression to get the size of globe without mentioning the sun's altitude difference. In other words, this textbook does not explain why we should get alternate angles to seek the size of globe.

② Also, textbook A uses the sun's rays in an experiment and added that you can use a light when it is cloudy. Students are bound to use a light whether it is a cloudy day or not.

③ Process 1 show that the experiment is developed by the two points at the same longitude. But, they overlooked the point that the shadow of the stick is also located at the same longitude at figure in the textbook.

④ This experiment should measure the angle of the stick, it's shadow and the distance between the two sticks. If the length of the stick is too long, it is impossible to measure it. Plus, it is tricky to measure the angle due to the curvature of the globe.

⑤ They let students work out a propositional expression for the measurement of globe without presenting it in summary 1 of the textbook. However, like Eratosthenes story, they did not present a way to calculate the size of globe so it is expected that the students will complete the challenged of forming a propositional expression.

⑥ The title of the experiment is <The Measurement of a globe>. In addition, the scale of the globe is not given so that students can not work out the problem of measuring the size of the actual earth. Awkwardly, the process of finding the radius of the globe is presented as the last step of the experiment.

#### 2. Textbook B

① Textbook B also uses the sun's altitude difference. However, this experiment only carries out the process of calculating the alternate angles by using a proportional expression to calculate the size of globe without mentioning the altitude difference of the sun. In other words, this textbook does not explain why we need to obtain alternate angles when seeking the size of globe.

② Textbook B also states that students can use the sun's rays.

③ The text tells us to select two points on a basketball to develop an experiment using two

points at the same longitude. However, it is not suitable to introduce the concept of longitude using a basketball because the longitude may be off due to an unknown degree of axis tilt.

④ It is difficult to affix a straw vertically, if it is stuck on using gum as the text dictates. And if the straw is too long, it is out of the question to measure it, so a proper textbook experiment should put a cap on the length of the straw. The experiment in this textbook does not mention maximum straw length, but the length of straw presented (figure 6) is obviously too long. Moreover, the explanation for how to measure the angle between the basketball, tip of the straw and the angle of the basketball's circumference was left out. Plus, it is difficult to measure the angle of a globe which's surface is curved.

⑤ This text presented the following to calculate the size of a basketball.

$$L : 1 = 360^\circ : \theta$$

This propositional expression uses the signs L, l and  $\theta$ , so, it is difficult for students to understand the notation. In addition, there is a problem in the summary section. When calculating R(radius), it would be better to replace L with  $2lR$ .

⑥ The title of this experiment is "Measuring the size of a basketball". We can think of a basketball as the earth but a text cannot accurately demonstrate the actual scale of the earth. Students are not able to calculate the size of the earth as a result. As an intensive course, the text directs students to calculate the radius of the earth by making use of the experiment, however it is confusing to solve this problem by presenting latitude without explaining the relationship between it and the sun's altitude.

### 3. Textbook C

① Textbook C does not refer to the sun's altitude difference. However, this experiment

carried the process of calculating the alternate angle using a proportional expression to get the size of the globe, without mentioning the sun's altitude difference. However, the text suggests that students calculate the alternate angle by suggesting use of the alternate angle and altitude difference between two points.

② This text also suggests that student use the sun's rays.

③ In the process of (na), the experiment is shown to be developed by using two points at the same longitude and they also suggest that the shadow of stick should be located at the same longitude.

④ An explanation for how to measure the angle between the globe, tip of the straw and angle of the globe's circumference was omitted. Plus, it is difficult to measure the angle of globe which's surface is curvy.

⑤ In the <Summary 2>, they ask for the circumference of the globe by calculating the distance between two sticks(l) and the latitude gap( $\theta'$ ), but the middle step to form a proportional expression is omitted, making the process impossible.

⑥ The title of experiment is <The Measurement of the globe>. In addition, the scale of the globe is not given, so students can't solve the problems of measuring the size of the earth, but merely calculate the size of the globe.

### 4. Textbook D

① Textbook D does not the sun's altitude difference. However, this experiment just carried out the process of calculating the alternate angle by using a proportional expression to get the size of globe without mentioning the sun's altitude difference. However, in the <interpretation1> they suggest why the students should work out the alternate angle by suggesting that students think of the relationship between  $\angle BB'C$  and angle  $\theta$ .

② The experiment is conducted using the sun's ray.

③ In the process of [I]the experiment is developed by using two points at the same

longitude, but this textbook overlooks that the shadow of the stick should be located at the same longitude.

④ In the process of ③ they present the process of connecting each point between the tip of stick and its shadow with thread, then measuring the angle  $\angle BB'C(\theta)$  with a protractor. However, I doubt that students are able to connect them precisely with thread and measure the angle with protractor.

⑤ The text presents the following formula to calculate the size of globe.

$$\text{Circumference of globe} : l = 360^\circ : \theta$$

This proportional expression helps students to easily understand the circumference of the globe by using it directly.

⑥ The title of experiment is 'The Measurement of the globe'. In addition, the scale of the globe is not shown, so that students can't solve the problem of measuring the actual size of the earth. This book directs students to simply find the size of the globe.

## 5. Textbook E

① Textbook E also does not use the sun's altitude difference. However, this experiment simply carries out the process of calculating the alternate angles by using a proportional expression to find the size of globe without mentioning the sun's altitude difference.

② Textbook E replaces the sun with a flashlight. The problem is that a flashlight cannot accurately replicate the sun's rays.

③ In process ①, the experiment is developed by using two points at the same longitude, but this textbook overlooks that the shadow of the stick should be located at the same longitude.

④ In the process of ③ the text presents the process of connecting the tip of stick B and shadow C with thread and measuring the angle  $\angle BB'C(\theta)$  with a protractor. However, I doubt that students will be able to connect them

precisely with thread and measure the angle with a protractor. In the case of the straw being too long, it is out of the question to measure it, so we should put a cap on the straw size. The experiment in this textbook doesn't mention this at all. Plus, it is difficult to measure the angle of globe whose surface is curvy.

⑤ They presented the equation for calculating the size of the globe as follows.

$$2R : 360^\circ = 1 : \theta$$

This proportional expression may be difficult for students to understand because it displays the circumference of the earth as  $2R$  and this experiment should be conducted using the radius of the earth, not the circumference.

⑥ The title of this experiment is 'The Measurement of the globe'. In addition, the scale of the globe is not shown; so that students can't work through the problem of measuring the size of the actual earth rather just calculate the size of the globe.

## 6. Textbook F

① Textbook F also does not use the sun's altitude difference. However, this experiment simply carries the process of working out the alternate angle by using a proportional expression to arrive at the size of globe without mentioning the sun's altitude difference. However, The additional question in the process of 4 allows students to have the opportunity to inquire about why they must work out alternate angles such as  $\angle BB'C$ .

② This text directs students to put the globe in the sun on the playground.

③ In the process of ①, the experiment is shown to develop by the two points at the same longitude, but this textbook overlooks that the shadow of the stick should be located at the same longitude as well.

④ In the process of 4, the text presents the process of connecting each tip of stick B and

shadow C with thread and measuring the angle  $\angle BB'C(\theta)$  with a protractor. However, I doubt that students are able to connect them precisely with thread and measure the angle with a protractor. This is a sensitive process and the chance of error is too great.

⑤ The formula directs students to form a proportional expression with the length of the arc. Of course, there are some students who will form it with length of arc and a central angle. However if mentioned specifically; how Eratosthenes measured the size of the earth, the problem could be easily solved. More references must be given to Eratosthenes thoughts and processes.

⑥ The title of the experiment is named <The Measurement of the globe>. In addition, the scale of the globe is not shown, so that students can't work out the problem of measuring the actual size of the earth rather than the size of the globe. Awkwardly, the process of seeking the radius of the globe is presented as the last step of the experiment.

#### IV. Conclusion and suggestion

This study is focused on comparing and analyzing 6 different second grade science textbooks in Korean middle school. Eratosthenes's measurement of the size of the earth is included in each text. I am suggesting a cohesive and effective experimental structure for future texts.

The conclusions of this research are as follows.

First, Eratosthenes estimated the size of the Earth by measuring the distance separating two distant locations using their angular separation; which are determined by measuring the sun's altitude with sticks at the two different locations on the same latitude.

Publishing companies must include the concept of the sun's altitude. However, some of them don't mention it. As such, the concept of the sun's altitude must be introduced to measure the size of the Earth.

Second, a reduced size globe is used as the

actual earth so; the sun should be replaced with reduced light as well, which is not the case. Here are two reasons. First, the higher the latitude on the earth, the lower the altitude of the sun according to the experiment of changing seasons in the 6th grade, elementary textbook but, there is happening the higher the latitude on the earth, the lower the altitude of the sun according to where you observe it on that day. The other is if you measure the altitude of the sun at the same time and place, the value of the sun's altitude should be the same, but if it is not, students may become confused. Explanations for such variables must be clearly put forth in order to have easily understandable concepts.

Third, you have stressed that there are 'two points at the same longitude' and that 'the shadow must be located on the same longitude' when randomly selecting two points. Most textbooks mention two points on the same longitude but, two of them design the experiment using the shadow the same longitude as well. This causes inaccurate calculations.

The other texts do not design the experiment using the shadow on the same longitude, which causes the experiment to not correspond to the experimental preconditions required for accuracy. The proper equation requires a relationship based upon the difference of the sun's southing and earth's central angle.

Fourth, we need a way precisely to measure the angle between a stick and its shadow. The angle between a stick and the shadow of it's tip is the sun's altitude difference. As such, if a measuring instrument capable of measuring the sun's altitude is on the market it should be used to measure the angle; it can offer an accurate calculation and more convenient experiment instead of using thread and a protractor.

Fifth, we need to present more specific proportional expressions for calculating the size of the globe. Three of the textbook companies employed a proportional expression in the experiment and three others did not. However, it is alright that proportional expressions are not

introduced in experimental stage, if it is mentioned how Eratosthenes measured the size of the earth. Yet, The researcher think it is desirable to minimize the hypothesizing and explain it in detail; if you want to bring proportional expressions into the equation.

Sixth, we need to calculate the size of the earth by presenting the scale of globe so as to attain the goal of the experiment. Two of the analyzed textbooks designed the experiment for the purpose of calculating the globe and three of them are designed to work out the radius of the globe which is not relevant to the purpose of experiment.

Lastly, we need to find a specific teaching-learning situation and have an understanding between teachers and students after recording and analyzing the actual classes analyzed for this related-study.

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