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Chapter 6

CLASSIFICATION OF STUDENTS' OBSERVATIONAL STATEMENTS IN SCIENCE

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ABSTRACT

Science educators, as well as students and scientists, are using the term 'scientific observation' in various contexts of science education. However, the definition, meaning, or purpose of scientific observation in the learning of science is so varied that it is quite often interpreted differently depending on the educators, contexts, or subject matters. Therefore, our understanding about students' observational activities can also be varied. The purpose of this study is to coordinate various views about scientific observation and to suggest a classificatory scheme to understand students' observational statements (OS). To do this, three observation tasks were used, and 127 students were asked to observe the task and to describe what they observed. Based on the analysis of students' OS, we classified four types of OS: common sense knowledge laden OS, scientific knowledge laden OS, distorted OS by prediction, and operational OS. In this study, the characteristics and classification standards for each type of OS are described. The distributions of classified students' OS were analyzed according to observational tasks, the type of OS, and the subject's age. As a result of this study, it is recommended that scientific observational tasks be developed with a clear purpose, according to what and how students should observe. Lastly, it is proposed that this study serves as a guide in assessing students' observational activities.

INTRODUCTION

It is often said that scientific observation is not only a starting point, but is also integral to the process of scientific inquiry. More specifically, observation is involved in the context of the discovery of new knowledge, as well as in the context of testing existing knowledge. With a pedagogical purpose in mind, observation may also be used to experience some phenomena related to abstract science concepts.

However, the term 'scientific observation' is used in many different ways. For instance, in the area of the philosophy of science, inductivists have believed that objective observation is possible and that the generation of new scientific knowledge originates from unprejudiced and unbiased observation. Hanson, however, by introducing a notion called 'theory-laden observation', claimed that the "*Observation of x is shaped by prior knowledge of x*"(Hanson, 1961, p.19). Falsificationinsts, like Popper, also admits that observation is guided by and presupposes theory, and therefore claims that theory is suggested as rather a speculative and a tentative hypothesis by the human intellect, than discovered by objective observation (Chalmers, 1986). Moreover, when theory is tested, it can survive even when conflicting observational evidence is presented. Lakatos, therefore, pointed out that observation statements alone could not lead to falsification (Lakatos, 1994, p.35; Park et al., 2001).

According to some science educators, the scope of observation is often established in various ways. Some restrict observation to visual perception (Martin 1972), while others broaden it to include other senses - smell, touch, hearing, or taste. Moreover, Chadwick and Barlow (1994) noted that, when making observations, students might use simple instruments, such as thermometers, rulers, clocks, or magnifying glasses.

There are also various opinions about the relationship between observation and other inquiry process skills. For instance, Heath (1980) viewed observation as involving activities of discriminating or categorizing sensory input. Also, the aspects to be observed in a given task are dependent upon what the intention of the observation is. When students observe 'something', it may be features, shapes, or colors of an object, the process of change with time, differences between before and after a change, or the event itself. In light of this, Haslem and Gunstone (1997) summarized that scientific observation is not a process to be carried out in isolation, but actually a very complex process.

Although almost all science educators and philosophers of science accept the view of the theory-dependence of observation (Gillies 1993), science educators often interpret the meaning of theory-laden observation in different ways. Martin (1972) suggested two types of theory-driven observations - 'primary cognitive' and 'secondary cognitive' observations - in which both forms of observation contain the observer's belief or cognitive states. He pointed out, however, that in neither case was a conscious inference or interpretation involved. Hodson (1986), on the other hand, proposed three stages of observation: raw data, sense experience, and observation. According to his view, raw data becomes sense experience by adding unconscious interpretation, and adding conscious interpretation to sense experience creates observation. He claimed that the process of adding conscious interpretation was a crucial one in science because, in this process, the observer determines whether he/she accepts the sense experience as true and acceptable evidence or not. In other words, Hodson viewed scientific observation as involving interpretation in nature. Millar (1991), by dividing the observer's background knowledge into scientific and non-scientific, noted that not all observation was influenced by theories that could be reasonably termed scientific. In other words, if children make an observation influenced by 'common-sense theories', that is, by 'non-scientific knowledge', then we do not call this sort of observation 'scientific theory-laden observation'. For instance, the observation statement that "The temperature of the inner side of the flame of a candle is higher than the outer side" can be regarded as a scientific theory-laden observation because, without directly measuring or observing the temperature of the flame, the observer uses the scientific knowledge that "the temperature of the flame differs according to the color of the flame" when describing his/her observation. But the statement that "The flame of a candle has different colors" is not a scientific theory laden observation because special scientific knowledge is not used in describing the observation.

In relation to students' observational activities, Haslem and Gunstone (1997) investigated how science graduates understood observation and how they approached the task of observing by asking the graduates students the following two questions: "What does the word OBSERVING mean to you?" and "What do you do when you are asked to observe?" Also, Gott and Welford (1987) categorized observation tasks according to question types (e.g., tasks asking to describe/classify objects/events or to identify variables, and so on) or resources (e.g., task involving naturally occurring or man made objects/events, and so on), and provided assessment criteria based on whether students used the appropriate theoretical idea or not.

Even in theses two studies, however, it is not sufficient to understand types or characteristics of students' actual observational statements (OS). In other words, there is little that has been analyzed as to how students actually make observations and how their OS can be classified according to the characteristics of their observations.

The main purpose of this study is to analyze the characteristics of students' OS and to classify students' actual OS based on their characteristics. The distributions of students' classified OS were analyzed according to observational tasks, the type of OS, and the subject's age. Finally, implications and suggestions for teaching and assessing observation in the context of scientific inquiry were presented.

PROCEDURE

Observation Tasks

When students observe something, there are many types of observational tasks. Those tasks can be divided according to the purpose of observation, types of objects/events to be observed, or observation method and so on. In this study, we divided observation tasks according to what they observe:

- Observing the state of an object
- Observing an event
- Observing the predicted result

Task I: Observing the State of an Object

In the first observation task, students were asked to describe what they observed about a burning candle. We call this the 'Candle' task. In this task, students can observe various features of the state of an object, such as its shape, color, smell, tactile qualities or sound, and other distinctive features using various sensory organs. 'Observing the rocks' or 'Observing the insects' can be other instances of this task I. In this case, students were expected to observe something as many and precisely as possible and to notice the major features. For instance, in a certain chemistry textbook, the authors describe 53 OS for a burning candle, and advise observers to describe their observations quantitatively as well as qualitatively using all possible senses. They also comment that OS does not presume the importance of an observation, that is, they say that the observation that a burning candle does not emit sound deserves to be described (Pimentel, 1963; pp. 449-450).

Based on observations, students may classify or categorize their observations (e.g., classifying rocks according to color or size of minerals), construct certain regularities (e.g., all insects consists of three parts - head, thorax, and abdomen), relate their observations to scientific concepts (e.g., the shape of iron filings around a bar magnet can be related to the concept of magnetic field), or try to explain their observations using scientific concepts (e.g., the flickering flame of a candle can be explained by air convection).

Task II: Observing an Event

Here, we let students describe what they observed after pulling one of two bobs of a double pendulum towards the observer and releasing it (Figure 1). We call this the 'Double Pendulum' task. In this task, students observe how an object changes over time as well as the characteristics of moving bobs. Another instance of this type of task may be 'Observing water when it is heated'.

In this task also, students can carry out various activities based on observation, such as classifying or categorizing observations, constructing regularities, relating observations to scientific concepts, or explaining their observation as mentioned in task I. In addition, Observation task II can be used to illustrate abstract scientific concepts (e.g., a LED connected to a coil lights up when the magnet is pushed and pulled inside a coil by electromagnetic induction) or to demonstrate fantastic or novel phenomena (e.g., a neodymium magnet repels a small, thin glass rod because glass is a diamagnetic material).

Task II has various aspects in common with task I, but there are several differences between them. At first, task I is about a static object while task II is about a dynamic event. This distinction of 2 types of observational tasks is related to how our knowledge is constructed. According to Novak (1986), the construction of new knowledge begins with our observations of objects or events, consequently, concepts can be defined as perceived regularities in objects or events, or records of objects or events designated by a label (Novak, 1998, p. 21).

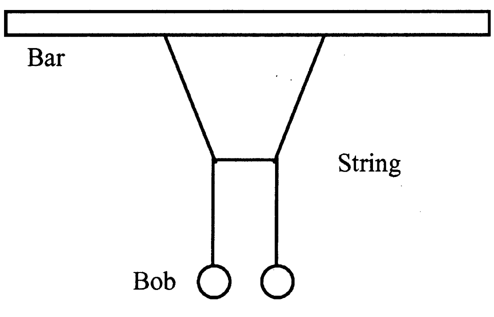


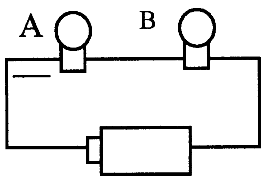
Figure 1. Double Pendulum

Task III: Observing a Predicted Result

The third observation task is specially prepared to investigate how a student's prediction affects the observation. To do this, before observation, we asked students to predict the brightness of two identical electric bulbs connected in series (Figure 2), and then let them describe what they observed about the brightness of the two bulbs. We call this the 'Bulb' task. Before observation, we selected only students who predicted that bulb A in figure 2 would be brighter than bulb B. This prediction is known as 'electric current attenuation model', which means that students who predicted bulb A would be brighter usually gave the reason that "Some current is used up in the first bulb" (Driver et. al., 1985).

'Observing two falling bodies in the air after anticipating which one will fall first' can be another instance of a task III. In this observation task, students observe either an object (e.g., a bright bulb) or an event (e.g., a falling object); therefore, task III is basically either task I or task II. However, the main difference between them lies in whether the student already has a specific prior idea, especially a misconception, about the observational result or not. For instance, if elementary school students who have no specific idea about the brightness of electric bulbs are asked to observe 'Bulb' task, then this task must be categorized as an observation task of type I.

1. Compare the brightness of two electric bulbs.



(1) Bulb A is brighter. ________________________________ ( )

(2) Bulb B is brighter. ________________________________ ( )

(3) The brightness of the two bulbs is the same ________________ ( )

2. Describe what you observed about the brightness of the electric bulbs.

Figure 2. 'Bulb' task.

Subjects

The subjects in this study were forty-two middle school students (grade 8), forty-five high school students (grade 10), and forty university freshmen (average age of 19 years). The subjects were selected randomly from schools and universities in Gwangju and Chongju, Korea. The number of students who participated in each task is shown in table 1. All subjects directly observed the task and described what they observed on a given worksheet.

Table 1. Number of Participants in Each Task

Grade	**Observation Task**			**Total**
	Candle	**Pendulum**	**Bulb**	
Middle School (grade 8)	15	15	12	42
High School (grade 10)	15	15	15	45
University	15	15	10	40
Total	45	45	37	127

RESULTS

Number of Students' Observational Statements (OS) According to Observation Tasks and Age groups

From 127 students, we obtained 675 observation statements (OS). Distribution of OS depending on the observation tasks and age groups is described in Table 2.

Table 2. Number of OS According to Observation Tasks and Ages

Grades	Observation Task			Total
	Candle	Pendulum	Bulb	
8	84 (5.6)*	54 (3.6)	33 (2.8)	171 (4.1)
10	122 (8.1)	93 (6.2)	41 (2.7)	256 (5.7)
University	125 (8.3)	109 (7.3)	14 (1.4)	248 (6.2)
Total	331 (7.4)	256 (5.7)	88 (2.4)	675 (5.3)

* Number in parenthesis indicates the average number of OS per student, that is, 5.6 is calculated from 84/15, where 15 (indicated in Table 1) is the number of grade 8 students participating in the 'Candle' task.

The mean number of OS per student (number in parenthesis in Table 2) was 5.3, varying with the observation task and the age group.

The order of overall number of OS according to the observation tasks ordered from most to least was: Type I > Type II > Type III. This tendency was consistent among all age groups. This result is closely related to the characteristics of the type of task. In the case of task I ('Candle' task), the aspects which should be observed are more open than other observation tasks; therefore, students were able to describe all of what they observed. While students observed the task II ('Double Pendulum' task), they focused generally on the change in motion of objects, as a result, they wrote a little about shape, color and other sensual perceptions of the pendulum. Also, when observing the brightness of electric bulbs ('Bulb' task), subjects observed mainly what they had anticipated, that is, the brightness of the bulbs.

Regarding age groups, older students generally described more observations than younger students. That is, there were an average of 4.1 OS per grade 8 student, 5.7 OS per grade 10 student, and 6.2 OS per university student. However, this tendency is not consistent according to the observation task.

Classification of Students' Observational Statements (OS)

We read all 675 OS, analyzing their various characteristics. For instance, some students used specific scientific terms or concept when describing their observations, tried to explain what they observed, observed the brightness of electric bulbs differently from others, or observed unexpected phenomena by performing additional actions during the observation. Based on this analysis, we categorized students' OS into the following 4 types:

- Type I OS: Common Sense Knowledge Laden OS
- Type II OS: Scientific Knowledge Laden OS
- Type III OS: Distorted OS by Prediction

- Type IV OS: Operational OS

Type I OS: Common Sense Knowledge Laden OS

As mentioned earlier, all observations are theory-laden. Yet if scientific theory can be discriminated from common sense knowledge (Millar, 1991), then theory-laden observation can also be divided into scientific knowledge-laden observation and common sense knowledge-laden observation.

When students described what they observed based only on common sense knowledge as opposed to scientific knowledge, we classified such OS as "Common Sense Knowledge Laden OS". In this case, sensual or optical inputs on the retinas of the observers' eyes are not different according to the observers if physical characteristics of their eyes are the same. And because common sense knowledge also is not different according to the observers, they all see the same thing, and as a result, their OS are nearly the same.

Table 2. Examples of Common Sense Knowledge Laden OS (Type I OS)

Candle Task	
	The color of the end of the wick is bright red.
	The flame becomes bigger and brighter when molten wax overflows from the lip of the candle.
Double Pendulum Task	
	The first bob nearly stops.
	The length of the two strings is the same.
Bulb Task	
	The brightness of the two bulbs is the same.
	The brightness of the bulbs sometimes varies.

Type II OS: Scientific Knowledge Laden OS

Based on the analysis of students' OS, we found several subtypes of scientific knowledge laden OS. At first, some students used scientific terms, concepts, or symbol/conventions to describe what they observed. For instance, a student who observed the 'Double Pendulum' task described, "*Period* of the first bob is similar to one of the second bob." Here, he/she used the scientific term 'period'. In this case, we classified his/her OS as 'scientific knowledge laden OS'. If a student who observes the iron filings around a bar magnet describes, "Iron filings are shaped along the *magnetic field*", his/her OS can also be classified as scientific knowledge laden OS.

Another instance of scientific knowledge laden OS occurred when a student interpreted their observation or inferred more than what he/she attended to sensually. For instance, a student who observed that the surface of molten wax was convex described, "*Surface tension* of molten wax *is large*." In this case, instead of simply describing the shape of molten wax, he/she used the scientific concept 'surface tension', and described what he/she observed as 'surface tension is large'. Of course, he/she did not measure the surface tension of molten wax directly but inferred the magnitude of the surface tension of molten wax based on its shape. Certain researchers (e.g., Martin, 1972) have regarded these OS as not observations but interpretations or inferences because such statements represent more than what the observer actually 'sees' based on his/her sensual information. However, some researchers (e.g., Hodson, 1986) viewed scientific observation as involving interpretation in nature. In this study, we adopted the latter view because we judged that it was not easy to discriminate the observation from interpretation or inference. This view is also based on the view that "All observations are theory laden".

The final subtype of scientific knowledge laden OS consists of statements explaining what students observed using scientific knowledge. One of the models of scientific explanation is the D-N (deductive-normative) model by Hanson (1965). According to Hanson, for the question 'Why did event E occur?', event E is explained deductively from scientific laws and initial conditions (Park and Han, 2002). Therefore, the statement that 'The flame flickers *by air convection*' can be viewed as involving a scientific explanation. That is, more than simply describing that the flame flickered, students explained the reason why the flame flickered using their scientific knowledge of 'convection'.

In summary, three subtypes of scientific knowledge laden OS can be summarized as follows (see Table 3):

- Subtype II-1 OS: OS involving specific scientific terms, concepts, or symbols/conventions
- Subtype II-2 OS: OS involving interpretation or inference using scientific knowledge
- Subtype II-3 OS: OS involving scientific explanation

Table 3. Examples of Scientific Knowledge Laden OS (Type II OS)

Task	OS	Subtype
Candle Task		
	The flame was blown by air convection.	II-3
	The surface tension of molten wax is large	II-2
Double Pendulum Task		
	Force is transmitted along the inter-linked string.	II-2
	The period of the second bob is similar to one of the first bob	II-1
Bulb Task		
	The energy has been transferred from bulb A to bulb B after being consuming at bulb A.	II-2
	The brightness of the two bulbs is the same because of the same electric current	II-3

OS Type III : Distorted OS by Prediction

When an observer makes a prediction before observing the result, his/her prediction may influence his/her observation, or even distort it. All students participating in observation task III (the 'Bulb' task) had the same prior idea that bulb A would be brighter (Figure 2). When we let students observe and compare the brightness of the two bulbs, some students described that "Bulb A looks brighter than bulb B", even though the brightness of the two bulbs was actually the same to me and to other observers who had the correct physical idea about the brightness of the two electric bulbs.

In our experiments, this OS was classified as 'Distorted OS by Prediction'. This type of OS is also another instance of theory-laden observation, but there is a major difference between type III OS and other instances of theory-laden OS (type I and II) mentioned earlier. In this case, an observer 'saw' the brightness of the bulbs in a manner which differed from sensual or optical information received by retinas in his/her eyes. That is, even though the visual image and sensual input on the retinas were the same for all of us, I saw that the brightness of the two bulbs was the same while they saw bulb A as being much brighter than bulb B. With respect to this, Hanson pointed out that "Seeing the sun is not seeing retinal pictures of the sun. … There is more to seeing than meets the eyeballs." (Hanson, 1961; 6-7)

Some philosophers of science say that observers of a common object see the same thing but interpret it differently based on their background knowledge. This view is correct for some instances of common sense knowledge laden observation (type I OS) and scientific knowledge laden observation (type II OS) mentioned earlier. In earlier cases, when students observed some objects or events, the visual data on their retina were the same, and they 'saw' it equally. But their OS were described differently because they used different scientific terms or concepts. For instance, imagine the following two observers: one observer who described, "Surface tension of molten wax is large" when he/she observed the 'Candle' task, and the other who described, "Viscosity of molten wax is large". Even though these two OS are different from each other, they were based on same visual information; that is, two observers saw the same thing equally. Therefore, if we ask them "What is the shape of the molten wax?", they should give the same answer, namely "It is convex". In the similar manner, OS can be described differently if the observers produce different interpretations, inferences, or scientific explanations.

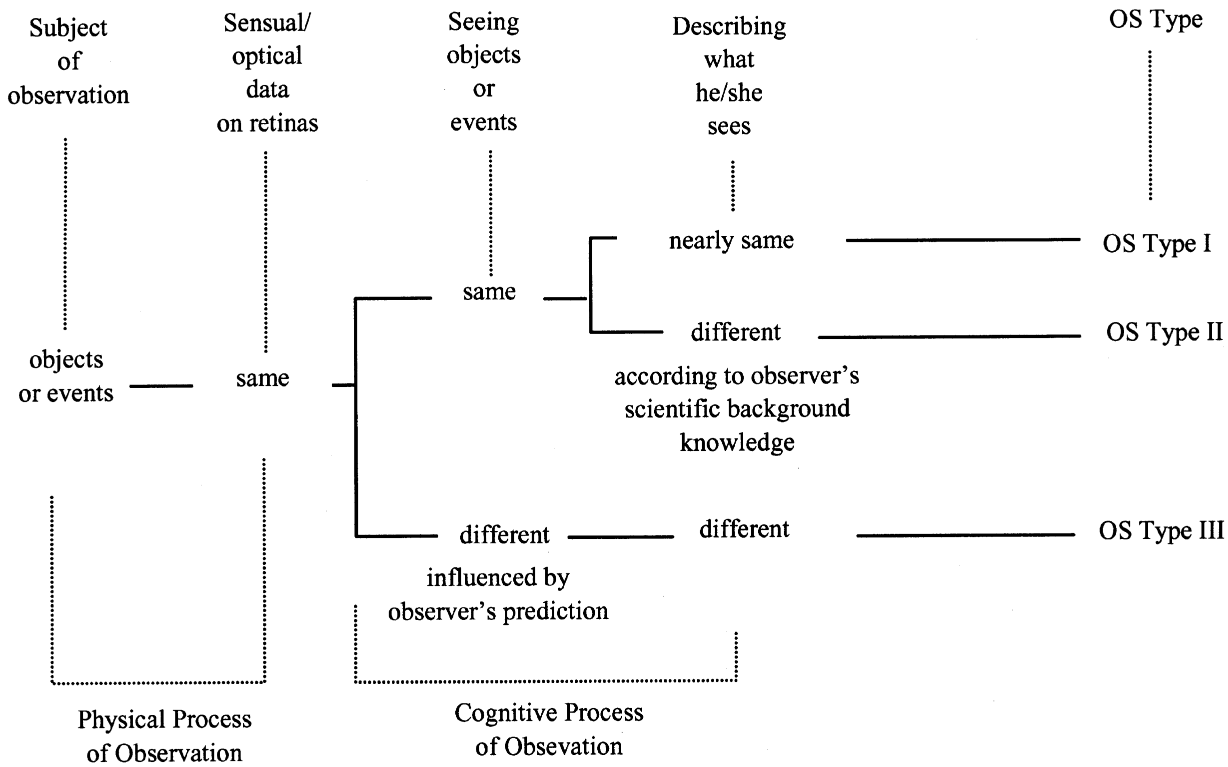


Figure 3. Classification of 3 Types of OS.

However, in the third type of OS 'seeing something' itself is different. That is, observers see objects or events differently. Someone observes that the brightness of the two electric bulbs is the same, while the others observe that one of two bulbs are brighter. This is the main difference between the third type of OS and earlier types of OS. Figure 3 shows the classification of three types of OS.

Type IV OS: Operational OS

In all observation tasks, the directions of how to observe and describe what was observed were simple. Major directions for observations were, "Light the candle with a match. Observe the candle and describe what you observed" in the 'Candle' task; "Pull one of two bobs towards you and release it softly. Observe the double pendulum and describe what you observed" in the 'Double Pendulum' task; and "Compare the brightness of two bulbs, describing what you observed" in the 'Bulb' task.

Even though directions written on worksheets were as simple as these, some students did something to the object, such as pushing, pressing, blowing, shaking, and so on. In some cases, students changed the initial conditions or other variables. For instance, in the 'Double Pendulum' task, some students described, "Changing the length of the string (of the double pendulum), the frequency is changed", or "Pushing the bob to the right, two bobs collide and move together". Some students used a simple instrument found near them, such as a pencil, ruler, beaker, and so on. For instance, in the 'Candle' task, a student described, "Even though I bent the wick of the candle with my pencil, the direction of the flame did not change", and another described, "When I put a beaker over the flame, the surface of the beaker steamed up".

In summary, we found that some students performed additional manipulations of the observational setting (e.g., bending the wick of the candle), or changed the initial conditions (e.g., pushing the bob to the right) or changed certain variables (e.g., changing the length of the string of the pendulum). In these cases, we classified such OS as "Operational OS" (see Table 4).

These observational activities are closely related to doing experiments in which experimenters try to discover the relationship between two variables by observing the change of a dependent variable in relation to the change of an independent variable, try to find new outcomes by changing the initial conditions of the experiment, or try to explore novel aspects as yet unobserved in previous experiments. These aspects will be discussed in a later section.

Finally, it is worth noting that operational OS can also be viewed as a result of theory-laden observation because there are disclosed intentions in the observer's mind whenever they perform any additional manipulations of the observational setting. However, in this study, we did not investigate the reason why the observers performed such actions. This aspect should prove to be an interesting research theme related to scientific observation in a future study.

Table 4. Examples of Operational Observation

Candle Task
When I blow, the flame quivers.
The molten wax becomes hard when I press it slightly.
Double Pendulum Task
Seizing the moving string, the bob begins to move faster.
Pushing the bob to the right, two bobs collide and move together.
Bulb Task
The brightness of the bulbs has not changed, even though the battery has been replaced.
The second bulb is automatically turned off when I turned off the first one.

Mixed OS

Certain OS are both common sense/scientific knowledge laden OS and operational OS. For instance, "Seizing the moving string (type IV OS), the period of the moving bob decreases (type II OS)" is one case of mixed OS with operational OS and scientific knowledge laden OS. And if students describe their observation with "Bulb A looks a little brighter when the battery is changed replaced", then this OS can be regarded as mixed OS with type III OS and type IV OS.

Therefore, students' OS types can be diagramed by 'network analysis' (Bliss et al., 1983) as in Figure 4. That is, there are various combinations of students' OS types, for instance, type I, II, III, I and III, II and III, I and III with IV, II and III with IV, and so on.

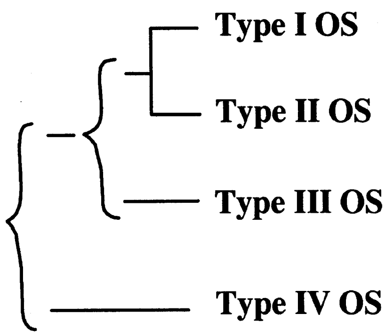


Figure 4. Network of Students' OS Types.

Non-observational Statements

Even though we let students describe what they observed, some students (i) *described their feelings, beliefs or judgments*, (ii) *predicted something that had not yet been observed*, or (iii) *asked questions*. Those statements, consequently, were classified as non-observational statements. Table 5 shows some examples.

Table 5. Examples of Non-Observational Statements

Candle Task
The candle is a useful thing.
Double Pendulum Task
If there is no gravitation, the bobs will move permanently.
Bulb Task
Does the quality of the envelope (of the bulb) affect the brightness?

Distribution of the OS According to the OS Types, Tasks, and Ages

According to Table 6, there was an average of 5.3 OS per student, of which 4 OS were the common sense knowledge laden OS (type I OS), but only half of the students described one scientific knowledge laden OS (type II OS). Even in the 'Candle' task, only one OS was a type II OS among the total of 7.4 OS. Therefore, we can conclude that students in an ordinary school settings generally describe using more common sense knowledge laden OS than scientific knowledge laden OS. However, if doctors observe the X-ray film of the patient, or if physicists observe the photo obtained from the cloud chamber, almost all their OS may be scientific knowledge laden OS.

In the case of the 'Bulb' task, half of the students' descriptions were type III OS (the mean number of distorted OS by prediction per student is 0.5 in Table 6). From this, we can conclude that the effect of the students' predication on the observation of the brightness of the electric bulb was substantial.

Table 6. Number of OS According to the OS Types and Observation Tasks

OS Type	Observation Tasks			
	Candle(N=45)	**Pendulum(N=45)**	**Bulb(N=37)**	**Total (N=127)**
Type I	257(5.7)	222 (4.9)	35 (0.9)	514 (4.0)*
Type II	43 (1.0)	14 (0.3)	11 (0.3)	68 (0.5)
Type III	—	—	19 (0.5)	19 (0.5)†
Type IV	22 (0.5)	11 (0.2)	14 (0.4)	47 (0.4)
Others	9 (0.2)	9 (0.2)	9 (0.2)	27 (0.2)
Total	331 (7.4)	256 (5.7)	88 (2.4)	675 (5.3)

* The number in parenthesis indicates the average number of OS per person, that is, 4.0 is calculated from 514/127.

† Students' predictions were not identified in the 'Candle' and 'Double Pendulum' tasks; therefore, in these cases, there were no type III OS. Here, the mean of 0.5 is calculated from 19/37.

In Table 7, it can be observed that older students gave descriptions with more type I OS than younger students (2.8, 4.5, and 4.7 for each grade, respectively), however, there was no difference among grade groups in the average number of type II OS (0.5, 0.6, and 0.5 for each grade, respectively). For type III, more high school students (12 students among 15 or 80%) and university students (6 students among 10 or 60%) utilized type III OS than middle school students (only 1 student among 12, that is 8.3%). In table 6, it was noted that the effect of prediction on observation was great; however the effect of prediction on observation differs according to ages. According to table 7, the effect of high school and university students' predictions is more substantial than that of middle school students. This may be due to the fact that the predictions of older students are more stable and stronger than those of middle school students. This does not mean, however, that older students have a well-organized knowledge of simple electric circuits.

Table 7. Number of OS According to the OS Types and the Ages

OS Type	Grades			**Total**
	8 (N=42)	**10 (N=45)**	**Univ. (N=40)**	**(N=127)**
Type I	125 (2.8)[1)]	201 (4.5)	188 (4.7)	514 (4.0)
Type II	20 (0.5)	27 (0.6)	21 (0.5)	68 (0.5)
Type III[2)]	1 (0.1)	12 (0.8)	6 (0.6)	19 (0.1)
Type IV	17 (0.4)	6 (0.1)	24 (0.6)	47 (0.4)
Others	8 (0.2)	10 (0.2)	9 (0.3)	27 (0.2)
Total	171 (4.1)	256 (5.7)	248 (6.2)	675 (5.3)

The number in parenthesis indicates the average number of OS per student.

The number of grade 8 students was 12, grade 10 students were 15, and university students were 10.

As a result, the major findings from tables 2, 6, and 7 can be summarized as follows:

- Generally, older students used more OS in their descriptions.
- The order of overall number of OS according to the tasks was: Task of observing the state of an object > Task of observing an event > Task of observing the result after making prediction.
- A large portion of the students' OS was included in the type I OS (common sense knowledge laden OS). It was also found that students in an ordinary school context generally used more type I OS than type II OS (scientific knowledge laden OS) in their descriptions. This tendency did not depend on age grouping or observation task.
- The effect of students' prediction on the observation was substantial, but this effect varied according to age grouping. That is, type III OS were used by more high school and university students than middle school students.

IMPLICATIONS FOR TEACHING AND ASSESSING OBSERVATION

When designing observation lessons in the context of scientific inquiry, science instructors should determine what and how students observe. In this study, three types of observational tasks can act as a guide for teachers to determine what students observe (that is, objects, events, or results predicted by the observer). Furthermore, to determine how students observe, four types of OS found in this study (Figure 4) can be used because each type of OS is closely related to the objectives of the observation activity as follows:

At first, if an observation task is aimed at training students in an observational skill itself, that is, to observe various features of object in as many ways as possible and as precisely as possible, to observe specific aspects which cannot be easily observed, and to facilitate objective observations in an unbiased way (we will call this the first purpose of observation), then the first type of OS (common sense knowledge laden OS) will be good enough for this task.

If, however, the purpose of the observation task is to understand or explain scientifically why something happens, or to connect observations with relevant concepts of science (we will call this the second purpose of observation), then the second type of OS (scientific knowledge laden OS) needs to be utilized in this task.

Moreover, if observation is used to generate cognitive conflicts in the mind of students who may have misconceptions (we call this the third purpose of observation), it may be important that students should objectively observe without any distortion influenced by prior misconceptions (Type III OS), and then recognize the similarities and differences between the observational result and its prediction.

Further, if the main purpose of the observation is to search or explore objects/events worth investigating in the context of open-ended scientific inquiry (we call this the forth purpose of observation), more various operational observations (type IV OS) should be encouraged.

If we clarify the purpose of observation as mentioned above, then the purpose of observation needs to be reflected in the written directions of the worksheet for the task. For instance, for the first purpose of observation, the directions for observation can be written as follows: "Describe what you observe as much and as precisely as possible. Especially, try to observe something which cannot be easily observed. When you observe, you may use all your senses, such as touch, smell, hearing, and taste, as well as visual perception." And if needed, when using the sense of smell or taste, a particular method or technique for observation may be presented in order to promote efficiency and safety.

Similarly, for the second, third, and fourth purposes of observation, the directions for the activity can be written as follows:

- For the second purpose of observation: "Describe what you observe. When describing your observation, you may use specific scientific terms/concepts. In addition, you may describe what you infer based on your observation, or you may explain your observation using appropriate scientific knowledge."
- For the third purpose of observation: "Describe what you observe and compare your observation with what you predicted before the observation".
- For the fourth purpose of observation: "Observe various aspects and try to find special aspects worth investigating more in-depth. When you observe, you may change observational settings, initial conditions, or observation methods, and you may use simple instruments around you to explore new aspects."

If the purpose of the observation task is clarified, then the students' observational activities can be assessed based on the given purpose. For instance, if the observation task is given to the students with the first purpose, then "How many observations are made?", "Does the student describe observations precisely?" "Does the student observe something which cannot be observed easily?", "Does the student use multiple senses?" may be included in the scoring system. Also, we can give demerit marks for any type II OS.

However, if 'Double Pendulum' task is presented to the student with the second purpose of observation, like APU (Table 8), whether the student makes specific observations needed to understand the concept of 'energy transfer' or not can be the standards for scoring.

Table 8. APU Mark Scheme for Observation of Double Pendulum (APU 1984) (Category 3, Ages 13 and 15)

Observation	Score
Black sphere (the second bob) starts moving	1
Black sphere swings further each time	1
Yellow sphere (the first bob) slows	1
Yellow sphere (nearly) stops	1
Wood (inter-linked rod) starts to move	1
Cycle repeats itself	1
Black swings about as far as yellow	1
(Any of above points) Subtotal	5

The following aspects can be added to the scoring standards for the second purpose of observation:

"Are the scientific terms/concepts that the student uses when describing his/her observation correct?", "Are the student's inferences based on his/her observation appropriate?", or "Are the student's explanations about his/her observation valid?".

In the case of the third purpose of observation, the most important assessment standard will be whether or not students observe objectively without bias and without any influence of prior predictions. Here, the observation alone is not sufficient. If students observe something that conflicts with their prediction, students should recognize the differences and similarities between the observational result and their prediction. Therefore, following another assessment standard may be needed: "Does the student identify the differences or similarities between the observational result and his/her prediction in detail?"

Finally, if the observation task has the fourth purpose, the assessment standards may be: "Does the student observe special aspects worth investigating by further inquiry?", or "Does the student observe something interesting which others do not usually observe?"

In summary, only when the purpose of an observation task is clearly designated and there is a criteria scheme that can be used to classify students' OS, we can reasonably assess students' observational activities. We hope that the results of this study will be useful in assessing the students' OS, as well as in understanding and classifying them.

SUMMARY AND CONCLUSIONS

In this study, using three observation tasks (observation of an object, an event, or the result predicted by prediction), students were asked to observe and describe what they observed. Based on the analysis of 675 observation statements (OS) from students, we classified students' OS into four types: common sense knowledge laden OS, scientific knowledge laden OS, distorted OS by prediction, and operational OS. Then, the distributions of classified students' OS were analyzed according to observation tasks, the type of OS, and subjects' ages.

For teaching and assessing students' observational activities, we suggested four types of purposes of scientific observation: a purpose for training in observational skills themselves, a purpose for understanding/explaining observations or relating observations to scientific knowledge, a purpose for generating cognitive conflict, and a purpose for encouraging the search and exploration of more aspects worth investigating.

We also discussed how the four types of OS classified in this study related to the purposes of observation, and how the purpose of scientific observation can be reflected in the directions written for the observation task. Finally, we suggested scoring standards for each purpose of scientific observation.

When science educators teach scientific inquiry, it is necessary to understand the nature of scientific inquiry. This is one reason why philosophy of science is helpful in science education. Therefore, a discussion about the nature of scientific observation, which is one of the scientific inquiry process skills, based on the philosophy of science is required. Moreover, understanding the actual students' activities when they observe certain physical phenomena gives concrete foundations on which science teachers may design and assess the observational activities.

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