The Middle School Students' Knowledge State Analysis about Light

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Abstract: In this study, we developed and applied 15 evaluation questions about light to 30 middle school students. Then we used the theory of knowledge space and analyzed the middle school students' knowledge state about light. By schematizing the hierarchy from it, we intended to not only measure students' knowledge state about light, but use it as the basic materials to improve teaching methods. To achieve the purpose of this study, we analyzed the evaluation results and individual knowledge state and hierarchy of questions. As a result, there were different knowledge structures in the individual or groups, and we found that we should diagnose them differently. In addition, we have had implications that it has the connection with each questions and the individual knowledge state.

Key words: Knowledge Space, Knowledge state, Hierarchy, Evaluation

Ⅰ. Introduction

Many researchers has pointed out that students don't have full understanding about the concept about light (Buty & Mortimer, 2008; Galili & Hazan 2000; Glodberg & McDermott, 1986; Guesne, 1985; Stead & Osborn, 1980; Wyrembeck & Elmer, 2006). Therefore, they have carried out many studies to solve these problems (Kwon et al., 2006; Oh & Kim, 2002; Lee et al., 2004; Buty & Mortimer, 2008; Wyrembeck & Elmer, 2006). Many teachers as well as students don't have a systematic concept about light and have difficulties in teaching a right scientific concept about it to students. They also have difficulties in teaching and learning about light. Because of this, teachers can not give them systematic feedback on their evaluation (Paik & Jung, 2009; Lee et al., 2004; Jung & Kim, 2005; Akerson & Morrison, 2006). Wenglinsky (2000) suggested it is a teacher that have a great effect on students' academic achievement. Nevertheless, students do solve the problems by applying what they already know and try to understand its structure of problem by applying what they already know. Sometimes acquire new knowledges with a creative ideas (Anderson, 1995). Durva (1985) said human's intellectual development has a sequence of systematization of cognitive functions. Low-leveled functions is based on the high-leveled when learning and there is the hierarchy

when we acquire functions related to a specific knowledge system. Consequently, we can regard the hierarchy of concept as a essential element to carry out high-leveled functions in learning (Jung et al., 1996; Bergan, 1980). We can also know which elements and functions students should study to reach the final purpose of learning. The hierarchy of scientific concept makes them know about the close connection and the order between subordinate concepts and super ordinate concepts (Bart, 1976). Therefore, through the post-learning to be hierarchial with pre-learning, we diagnose students' knowledge state and analyze and deal with the cause of the loss. We have to consider teaching/learning and students' level of hierarchial concept to handle the loss (Yoon & Kim, 2010). There is the theory of knowledge space to analyze students' hierarchial concept (Kim et al., 2007; Park et al., 2005; Park, 2010; Byun et., 2004). This theory is based on the hierarchy of knowledge that is claimed by Jean-Paul Doignon and Jean-Claude Falmagne (1999) and is the great way to analyzed students' knowledge state and hierarchy. It is appropriate to strongly hierarchial subjects such as mathematics and science. Scientific Education Laboratory in Kongju National University (2002) suggested that when analyzing the evaluation results, we could measure student's hierarchy according to whether choose a right answer or not, not using the number of student's grade and don't make a mistake like leveling the grade.

There is the earlier studies using the theory of knowledge space and the analysis method of knowledge state as the tool of the evaluation. Kim et al., (2007) developed questions about the frictional electricity and applied it to students in the second year of the middle school. As a result, we can compare students' knowledge state after studying with who did not and see their structure of the scientific concept visibly. Students can be diagnosed before and after learning. Preliminary physics teachers analyzed the hierarchy of physical concept by grades using the analysis method of knowledge state and the theory of knowledge space. Park et al., (2005) analyzed the evaluation results and apply it to the efficient curriculum as the basic materials in physics education. With the theory of knowledge state, Park (2010) analyzed students' knowledge state of physics class about power and movement part in the gifted's science education institute managed by a university. From this, he schematized the hierarchy about the concept of power and movement and especially used to improve the teaching method about the wrong concept as the basic materials in physics education. Kim et al., (2011) classified high school students' science knowledge in the lesson of current and voltage and developed evaluation questions on physics with the theory of knowledge state. From this, they schematized the hierarchy high school students' knowledge state and analyzed each individual's hierarchy. It has been a milestone for individualized learning.

These earlier studies schematized the hierarchy of knowledge as the method of analyzing the evaluation results from students. However, the hierarchy of knowledge state of light for the middle school students has not been studied so far. The study

that analyze the appropriateness of curriculum and science in the middle school says that the lesson about light is one of the most difficult ones to students than any other part of physics (Lee et al., 2006).

Therefore, we analyzed middle school students' knowledge state with the theory of knowledge space. Schematizing the hierarchy of knowledge state from this, we tried to not only grasp the knowledge state on light but apply it as the basic material to improve the method of the teaching. To achieve the purpose of the study, we developed evaluation questions on light and applied to middle school student first and analyzed the evaluation results of their knowledge state on light. Lastly we analyzed the hierarchy in questions and each individual's knowledge state.

Ⅱ. Methods

1. Participants

we evaluated 30 of middle school students who listened the online science lecture for the gifted managed by the gifted's science education institute to analyze their concept of light. It is located in a K National University of a city in Chungcheongnam-do province. The education course is divided into the online lecture and the camp and make students be self-initiated. In the way of the selection, first, students applied for it through the school principal's recommendation and second, they was selected by examining their career papers. Final successful candidates joined the homepage of the gifted education institute in K National University and was examined their the qualifications. After that, they was accepted in the online education. There were 136 applicants in total. Students had the entrance ceremony and the orientation for 7 years and were educated the online education 12 weeks during the first semester. The candidates were selected when completed the formative evaluation and homework. The candidates stayed in the camp for training for two nights and three days during summer vacation. The candidates who finished the camp training took the online education 12 weeks during the second semester and the final selection was made. Even though the final candidates were selected, the course was not completed in case of falling short of the standard in the gifted education institute. The completion conditions were: the candidates were selected through the comprehensive online evaluation during the first semester and had to join a camp training during vacation. they had to take the online education more than two thirds of the first and the second semester and do more than 70 percent of the homework in the online. There were 66 students who stayed the camp for training during vacation. However, we have studied it for 30 students a class.

2. The Evaluation Question

We presented evaluation criteria before we made evaluation questions about light based on the contents of science and curriculum. First, we classified science knowledge into three area of the fact, the concept and the law/principal referring to the criteria for classification of the national evaluation system development of science knowledge (Kwon et al., 1998) and analyzed the hierarchy of the evaluation questions. The questions was created with five questions and the multiple choices and time was limited within one hour. A physics education expert and two science teachers modified and supplemented the questions through pilot tests five times. After checking the validity of questions, we finally developed 15-question objective test. There are table 1 on the area and content of questions below. We applied these questions to 30 middle school students. And then the results were made the hierarchy with MS Office 2007 Excel and we analyzed knowledge state the individual and the grouped. The analysis process of the evaluation questions that is the purpose of this study are not directly related to the concrete content of them. we just had an interest in analyzing students' indirect response from this(변두원 등, 2004).

Table 1. Light concept area and content as evaluation question.

Question	Concept area	Science knowledge area	Content of question
1	reflection of light	fact	s shape of a letter reflected on a mirror
2	reflection of light	law/principle	a phenomenon of incidence of light upon a mirror.
3	reflection of light	law/principle	a rotation of mirror of light reflected on a mirror pass a point
4	refraction of light	concept	a phenomenon of the refraction of light
5	refraction of light	concept	a phenomenon of light passed from air to water
6	refraction of light	concept	explaining a movement of water waves passed from a point to another
7	refraction of light	law/principle	an incidence angle and a refraction angle of light given incidence obliquely in boundary surface from air to glass
8	dispersion of light	law/principle	the most refracted rainbow colors passing through a prism.
9	dispersion of light	concept	why light is broken into different colors by water drop and a prism.
10	reflection, refraction, dispersion of light	fact	the refraction and reflection of light in water drop when a rainbow is formed
11	reflection of light	concept	why a yellow flower is seen as yellow to our eyes
12	interference of light	fact	a shape of reflected waves surface after water waves head toward obstruction vertically
13	interference of light	fact	a shape of water waves reflected on a wall when a finger dips into washbowl
14	diffraction of light	concept	a phenomenon in diffraction of sound
15	diffraction of light	concept	in playing hide-and-seek, how we can hear despite hiding away

Ⅳ. Results and Discussions

We have analyzed the results of middle school students' concept of light who listened the online science lecture in the gifted education institute in K National University. We have also analyzed the evaluation results of 30 students a class and individual sampling and examined how each question has the hierarchy relation. We have diagnosed the individual and the grouped based on this hierarchy relation.

1. Analysis and diagnosis of students' knowledge state

Fig. 1 shows the evaluation results of 30 students a class. The dotted line boxes show how connected each questions are in hierarchy. Students' knowledge state is classified into three hierarchy groups on the reflection of light, the dispersion of light and the diffraction. Because the hierarchy of diffraction have not taught in the current curriculum systemically, we did not write about it.

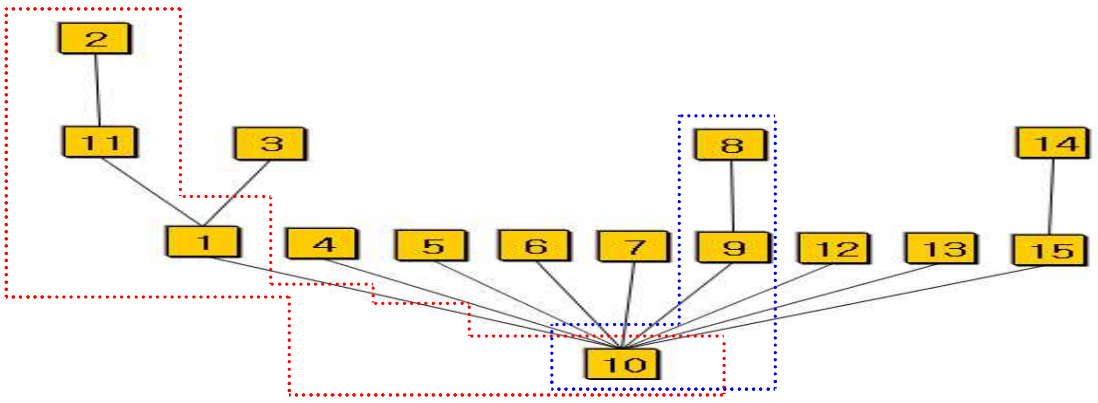


Fig. 1. knowledge State analysis of Middle School Students

When we saw how students' knowledge state of light forms into the hierarchy relation, there were the hierarchy relations of [question 10]-[1]-[11]-[2] and [question 10]-[9]-[8]. Most students gave the correct answer to the [question 10] because it is at the bottom. In the hierarchy of [question 10]-[1]-[11]-[2], [question 10] is the fact area about the refraction, the reflection and the dispersion of light in water drop when a rainbow is formed. [question 1] is the concept area about how the shape is when a letter is reflected on a mirror and [question 11] is the concept area about why a yellow flower is seen as yellow to our eyes. [question 2] is the law/principal area about how the phenomenon happen when light gives incidence upon a mirror. When light is reflected on a mirror, we can answer to how the reflection happen with boundary condition of medium from Fermat's principle of least time, Huygens' principle and Maxwell's equations and others. With

Fermat's principle of least time that light travels route to take the least time, we examined travel route of reflective light. That is, light reflected on a mirror reflect the same as an incidence angle and reflective light is on the coplanar line with an incidence light and a normal. They have to give the correct answer to the [question 10]-[1]-[11] to be correct to [question 2]. [question 10]-[1]-[11] have questions about the reflection of light in common and should be understood about it first. In the hierarchy of [question 10]-[1]-[11]-[2], [question 1] is ranked above [10]. [questions 1] is about how the shape is when a letter is reflected on a mirror and distance from a plane mirror to reflection is the same with one from a mirror to a object. The size of reflection is the same with one of a object and its left and right is changed. Each ray of light incident is reflected on a mirror and enters eyes. [question 1] is ranked above [11]. [questions 11] is about why a yellow flower is seen as yellow to our eyes. The colors of objects we see is the colors of light that one of the many colors is reflected or penetrated on objects. The objects appear specific colors because light for the object to emit or reflect is limited in the specific wavelength area and the optic nerve recognize it. However, some students have thought that the colors of objects change with not a light source or its interaction but the specific quality of them. In the hierarchy of [question 10]-[9]-[8], [question 9] and [8] is ranked above [10]. [question 10] is about the refraction, the reflection and the dispersion of light in water drop as explained and [question 9] and [8] is about the dispersion of light. [questions 9] is the concept area about why light is broken into different colors by water drop and a prism. [questions 8] is the law/principal area about which colors refract the most when rainbow colors passes through a prism. Generally the shorter the wavelength is, the slower the speed of light is. A refractive index of a medium depends on the wavelength and purple light's short wavelength is higher than red's. Therefore, purple is the most refractive and red is the least refractive. Through [question 10]-[9]-[8], we can know the principle. We analyzed the results of 30 middle school students' concept of light in the gifted education institute in K National University. we saw that there are the hierarchy relations of the reflection of light in [question 10]-[1]-[11]-[2] and those of the dispersion of light in [question 10]-[9]-[8]. According to the science knowledge area of the hierarchy group above, we can saw the structure of the fact-concept-principle/law from underneath and students found the questions of the principle the most difficult.

2. Analysis and diagnosis of sampling students' knowledge state

In this study. we examined how 30 students' knowledge states distribute on the analysis above. There are typical examples below one of them with sampling students' information. When we analyzed the hierarchy with the theory of knowledge space, we could know the hierarchy and the knowledge state not only of

the group but of the individual in that group. Fig. 2 is the analysis result of sampling student A's knowledge state. The square is the correct answer and the diamond shape is the wrong one.

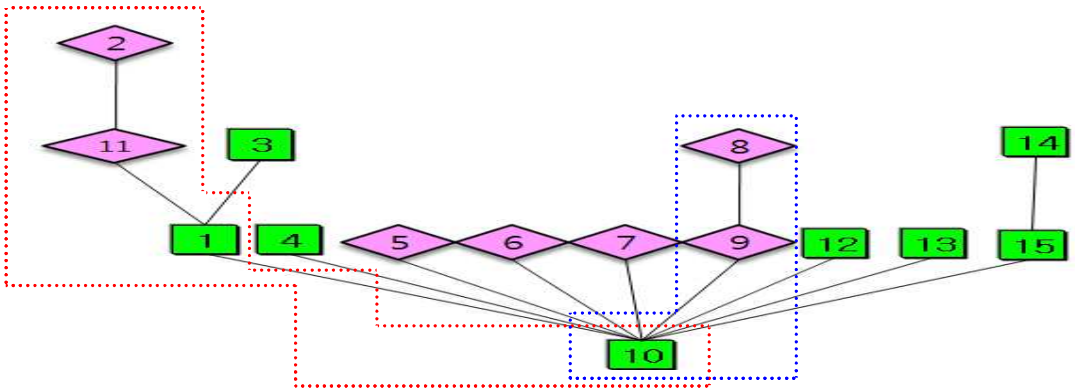


Fig. 2. knowledge State of sampling student A

Sampling student A had not the hierarchy of questions and had no the concept of the reflection and dispersion of light, and there were low connection with each question. That is, student A had not the hierarchy of knowledge state of the reflection, dispersion of light and the concept of light. Thus, the systematic individualized education about the concept is required for this student by analyzing the knowledge state of light.

In Fig. 3, sampling student B had the great concept of questions presented.

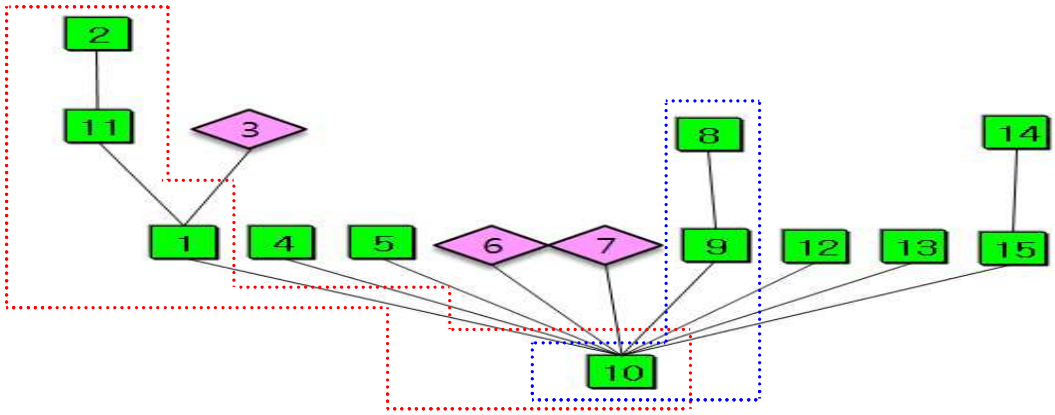
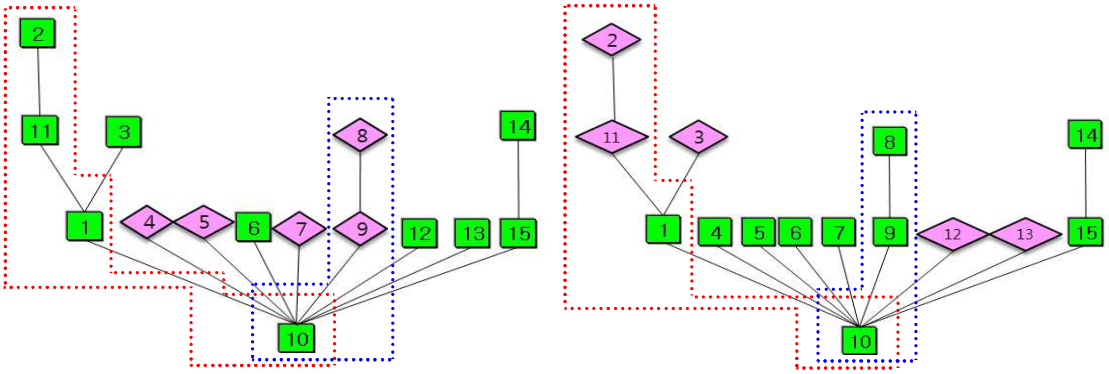


Fig. 3. knowledge State of sampling Student B

Student B got right answer in connective questions of the reflection of light in [question 10]-[1]-[11]-[2] and those of the dispersion of light in [question 10]-[9]-[8]. therefore, Student B had the systematic hierarchy of the reflection, dispersion of light and the concept of light.

Fig. 4 is students' hierarchy who have gotten the same score. Sampling student C and D had the great concept of questions presented in this study. On the other hand, even though got the same score, each individual had different knowledge structure and have to be evaluated differently.



(a) Knowledge State for sampling Student C (b) Knowledge State of sampling Student D

Fig. 4. knowledge State analysis of Sampling Students Getting Same Score

We could diagnosed that while sampling student C had the hierarchy of knowledge state of the reflection of light in [question 10]-[1]-[11]-[2], student C had not those of the dispersion of light in [question 10]-[9]-[8]. In contrast, while sampling student D had the hierarchy of knowledge state of the dispersion of light in [question 10]-[9]-[8], student D had not those of the reflection of light in [question 10]-[1]-[11]-[2].

As you see, two students who got the same score had different diagnosis results respectively and it is hard to see in the existing general evaluation with the number of score. There was a little difference, but the hierarchy of knowledge state is divided into two groups that had the great hierarchy and had not respectively. Although we presented the analysis results of just four sampling students- had the great hierarchy and had not, and got same scores-, we have actually diagnosed all 30 students who joined this study with the individualized evaluation. Had we diagnosed and compare students' evaluation results with the existing method in the field of education, they would have been considered as the same level of science knowledge with the number of score, ignoring their individual difference. Also, they could have continued to have a teaching and learning of the next step with the wrong concept that was not dealt with.

Consequently, the analysis results of individual knowledge state with the theory of knowledge space show that which student has a wrong concept in an area and would play a role of guiding about how to teach and learn in the future(Park, 2010).

Ⅴ. Conclusion and Suggestions

We developed the evaluation questions to analyze middle school students' knowledge state about light concept and compared hierarchy of the grouped with one of the individual by applying to them. We knew that their concepts of the reflection, the dispersion of light and the diffraction not to be written and that the knowledge state of them has been formed. By analyzing the students who were set up correctly on hierarchy of the knowledge state and who did not, we got the diagnosis and learned information about individual knowledge state. In the results, while student A was set up correctly on hierarchy of the knowledge state about the reflection and the dispersion of light, student B did not. Even though students who got the same point on questions of light, hierarchy of the knowledge state was different. Student C and student D have gotten the same point. Even though the one was set up correctly on hierarchy of the knowledge state about the reflection of light, he/she did not on hierarchy of the knowledge state about the dispersion of light. In contrast, although the other did not about it, student D set up correctly on hierarchy of the knowledge state about the dispersion of light.

In other words, even though students who got the same point, the individual has different knowledge state and have to be evaluated differently. We have found that analyzing the knowledge state with the theory of knowledge space make us learn about relation of each questions- the hierarchy- and individual knowledge state. We have known that the hierarchy from this is the evaluation tool to diagnose the grouped and individual's knowledge state.

It is essential to study about the hierarchy of learner's various knowledge such as the systematization of the teaching/learning, individualized learning and setting up the hierarchy relation. It is crucial to study about the hierarchy of science curriculum of physics lesson and what students know about it in the field of education. We hope that these diagnosis with knowledge space is considered when planning the teaching method and evaluating students on physics in addition to the lesson of light. Above all, there should be the study about the appropriate solutions to the hard lessons for student to understand and for current teachers to teach. We also suggested that there should be the qualitative research for why they have those knowledge state as well as the quantitative research to analyze individual's knowledge state in more detail.

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