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Scientifically Gifted Students' Conceptions of Nature of Science

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Abstracts : The purpose of this study is to assess gifted students' conceptions about nature of science (NOS). Scientifically gifted students who are expected to be professionals in the future should possess an adequate understanding of NOS that is firm foundation for scientific career. 47 volunteers from the 8th grade gifted science program in Seoul National University Gifted Education Center participated to answer questions inquiring NOS conceptions. Their answers were analyzed and compared to different groups such as non-gifted students and younger gifted students. As a result, gifted students' understanding of NOS appeared to surpass that of non-gifted students in many aspects and it seemed that gifted students formed their NOS view in early ages. The relative weakness in their NOS conceptions was found in understanding of scientific enterprise. Their strong misunderstanding about obstacles that minority people would face in scientific enterprise was noticed, too. They admitted that there has been discrimination in scientific enterprise, but they wrongly believed that outstanding scientists cannot be affected by it. Further studies will be required to probe more.

Keywords : nature of science (NOS), gifted science education, progress in NOS view

Introduction

The world is changing day by day. As Toffler (1984) once observed, we are now moving into the new age where ideas and problem-solving skills are much more valued than manufactured products. In this new era, the role of science is emphasized more than before and the role of science education also changes to meet the new requirements (Gallagher & Gallagher, 1994).

Apparently, there are two paths which science education should take to fulfill these requirements. One is to educate all students to be scientifically literate citizens for the future society and the other is to encourage and to help prospective students to be competent professionals in science.

Few would deny that science literacy is a goal for all students, whether gifted or not, to achieve through science education. Educating future scientists, however, requires more than achieving science literacy.

According to Heller (2002), "scientific giftedness" or "scientific ability" can be defined as specific thinking potential or a special talent for excellent performances in science. Then, what kind of factors could make these potentials or abilities to bloom to achieve scientific success? Heller (2002) mentioned that Trost and Sieglen (1992), as well as many other researchers, attempted to identify the most predictable factors for professional success in science. They suggested that domain-specific problem-solving abilities, motivational factors, and social leadership abilities are likely to be the strongest long-range predictors for scientific success. These factors appear to be closely related to subjects in NOS, scientific inquiry, scientific world view and scientific enterprise, respectively. It suggests that understanding adequate NOS conceptions could be the basis of blooming scientific giftedness.

As well known, there is no single, preferred definition of NOS (Lederman, 1992; Abd-El-Khalick & Lederman, 2000; Akerson *et al.*, 2000; McComas *et al.*, 1998). But the general agreement that is relevant to k-12 students has been achieved(Lederman, 1992; Akerson *et al.*, 2000) and this study was focused on that general agreement.

We tried to probe scientifically gifted students' understanding of NOS conceptions and to identify its characteristics by comparing to that of non-

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gifted students. We also tried to follow their progress in understanding NOS conceptions.

Procedure

Sample

The data were obtained from 47 students who enrolled in gifted science program provided by Seoul National University Gifted Education Center. All participants were 8th grade and came from all over Seoul.

To compare the gifted students' data to that of non-gifted students, the same questionnaire was given to another 47 students in a middle school in Seoul. This group of students was randomly selected among 8th grade students in that local middle school.

We need to trace gifted students' progress in NOS understanding, thus a group of 5th grade gifted students were also surveyed. These students were from suburban area near Seoul and were attending gifted science classes at a private institute.

Questionnaire

The test instrument used in this study was designed to assess k-12 students' progress in understanding of the NOS based on Benchmarks for Science Literacy (AAAS, 1993) and it contains 256 true-false items covering four groups of grade level; k-2, 3-5, 6-8, 9-12 (Lee, 2001).

Each item has a statement containing a key idea from Benchmarks statements.

Respondents are asked to answer "true", "false" or "I don't know" to each given statement. According to Benchmarks notion, "students know the idea" implies following three statements (AAAS, 1993).

Students can explain the idea in their own words.

Students can relate the idea to other ideas in Benchmarks.

Students can apply the idea in the new context.

The test instruments adopted this implication and three types of test-items were produced from the same, single key idea (Lee, 2001).

E-type question focuses on the ability of explaining the key idea. R-type question focuses on the ability of relating the key idea to other ideas in Benchmarks, while A-type question focuses on the ability of applying the key idea in the new context.

A respondent who fully understands the key idea is supposed to consistently answer all three types of question (Lee, 2001).

For the survey used in this study, 24 test items from 6-8 grade level were selected. They covered all three subjects in NOS; scientific world view, scientific inquiry, and scientific enterprise. All three types of items were included, too.

Meanwhile, 11 items were selected from 3-5 grade level and 6-8 grade level to survey 5th grade gifted students. The items contained similar ideas to items given to 8th grade students.

Data Collection and Analysis

24 selected test items were administered to 8th grade participants, both gifted and non-gifted. Independently, 11 selected test items were given to 5th grade students. In this case, these young children were allowed to explain themselves during the follow-up interview. Since the number of test items were relatively small and the number of participants were only 17, the follow-up interview was necessary to obtain useful information. The interview was done individually, after students answered the questions. Each student was encouraged to explain his/her idea about each answer and to give examples to support his/her answer.

After scoring was done, we calculated what percentage of students gave an acceptable answer to each item. Since each item represents a key idea of NOS, we interpreted respondents' thoughts about a particular NOS idea by each result.

Then, we compared gifted students' result to that of non-gifted students and tried to identify the difference and also tried to explain the possible cause of the difference.

Finally, we traced the change of gifted students' idea about NOS by comparing the result to that of younger students.

Results

Each items contains the key idea of NOS. Table 1 shows key ideas of all 24 items as well as what percentage of gifted students gave an acceptable answer to each item. A complete set of test items is provided in appendix.

Gifted students appeared to have acceptable views about scientific world view. 96% of respondents understood the tentative nature of science and 94% of them answered that there are very old theories still applicable. Also, 70% of them believed that the result of scientific investigation cannot always be the same.

For the scientific inquiry, most of gifted students understood how the scientific investigation proceed, how variables are controlled, and how different a particular scientific investigation can be from others. 75% of them correctly answered about the hypothesis and more than 70% of them understood the bias and prejudice which can occur in scientific investigations.

Scientific enterprise was the theme in which gifted students showed relatively weak understanding. Gifted students seemed to have strong awareness for the science ethics. 96% of respondents answered that human subjects should be informed about the risk that can happen during the investigation and they also knew the technology can provoke social and ethical controversy. In contrast, only 75% of them agreed to the importance of scientists' credibility. But notable weakness in NOS understanding was found in their understanding of discrimination in scientific community. 70% of respondents agreed that there has been discrimination toward the minority in scientific community,

Table 1. The Percentage(%) of gifted students' acceptable answer to each item that contains NOS idea

no	idea	T	F	N
1	Scientific World View(non absoluteness)	23.5	***70***	6.5
2	Scientific Inquiry(hypothesis)	21	***75***	4
3	Scientific World View(tentativeness)	***96***	4	0
4	Scientific World View(continuity)	***94***	2	4
5	Scientific World View(limitation)	***83***	11	6
6	Scientific World View(limitation)	23.5	***53***	23.5
7	Scientific World View(limitation)	6	***85***	9
8	Scientific inquiry(variety)	***92***	6	2
9	Scientific inquiry(process)	***92***	4	4
10	Scientific inquiry(controlling)	***90***	4	6
11	Scientific inquiry(bias & prejudice)	***74.5***	8.5	17
12	Scientific inquiry(bias & prejudice)	***72.5***	10.5	17
13	Scientific inquiry(bias & prejudice)	***81***	13	6
14	Scientific inquiry(bias & prejudice)	24	***62***	15
15	Scientific inquiry(bias & prejudice)	***81***	6	13
16	Scientific inquiry(bias & prejudice)	***66***	6	28
17	Scientific Enterprise(contribution)	6.5	***85***	8.5
18	Scientific Enterprise(discrimination)	70	15	15
19	Scientific Enterprise(discrimination)	85	***4***	11
20	Scientific Enterprise(contribution)	15	***70***	15
21	Scientific Enterprise(contribution)	21	***66***	13
22	Scientific Enterprise(ethics)	***96***	0	4
23	Scientific Enterprise(ethics)	***96***	2	2
24	Scientific Enterprise(ethics)	***75***	1.5	23.5

*thick, italic note means an acceptable answer

** T: true, F: false, N: I don't know

Table 2. The Percentage (%) of non-gifted students' acceptable answer to each item that contains NOS idea

no.	idea	T	F	N
1	Scientific World View (non absoluteness)	60	***30***	10
2	Scientific Inquiry (hypothesis)	40	***40***	20
3	Scientific World View (tentativeness)	***73***	10.5	16.5
4	Scientific World View (continuity)	***69***	14.5	16.5
5	Scientific World View (limitation)	***75.5***	9.5	15
6	Scientific World View (limitation)	20	***56***	24
7	Scientific World View (limitation)	20	***65***	15
8	Scientific inquiry (variety)	***79***	11	10
9	Scientific inquiry (process)	***65***	15	20
10	Scientific inquiry (controlling)	***55***	20	25
11	Scientific inquiry (bias & prejudice)	***56***	17	27
12	Scientific inquiry (bias & prejudice)	***54***	15	31
13	Scientific inquiry (bias & prejudice)	***60***	20	20
14	Scientific inquiry (bias & prejudice)	34	***51***	15
15	Scientific inquiry (bias & prejudice)	***61***	10	29
16	Scientific inquiry (bias & prejudice)	***60***	16	24
17	Scientific Enterprise (contribution)	20	***65***	15
18	Scientific Enterprise (discrimination)	***48***	18	34
19	Scientific Enterprise (discrimination)	64	***13***	23
20	Scientific Enterprise (contribution)	27.5	***42.5***	30
21	Scientific Enterprise (contribution)	38.5	***45***	16.5
22	Scientific Enterprise (ethics)	***83***	6	11
23	Scientific Enterprise (ethics)	***65***	10	25
24	Scientific Enterprise (ethics)	***61***	15	24

*thick, italic note means an acceptable answer
** T: true, F: false, N: I don't know

however, 85% of them showed their misunderstanding by answering that such discrimination did not affect celebrities in science.

Table 2 shows the result of the same kind of survey that was given to non-gifted students. As shown in Table 2, non-gifted students appeared to give relatively high percentage of neutral answer. It implies that they have relatively vague understanding. And the percentage of an acceptable answer was usually ranged from 50% to 65%. More than half of students seemed to understand about bias and prejudice in scientific investigations, process and controlling in scientific investigations, limitation in science and science ethics. But 60% of them showed to have unacceptable view that the result of scientific investigations should always be the same. And only 40% of them correctly answered about hypothesis. They also appeared to believe that discrimination did not affect celebrities in science.

Table 3 shows the result of the survey of 5th grade gifted students. It shows the result of 11 items which contain similar NOS key ideas to items given to 8th grade students.

Young gifted children showed to have acceptable views about tentativeness and continuity in science. They appeared to believe that the results of scientific investigations are not always the same and they also seemed to believe that anyone can contribute in scientific enterprise. In the area of scientific world view, 5th grade gifted students showed to have more acceptable view than non-gifted 8th grade students have.

They displayed the same misunderstanding about discrimination in science community as older students did.

Table 3. The percentage (%) of 5th grade gifted students' acceptable answer to each item that contains NOS idea

item no.	idea	T	F	N
1	scientific world view (non absoluteness)	12	***82***	6
2	scientific world view (non absoluteness)	***100***	0	0
3	scientific world view (non absoluteness)	***47***	41	12
4	scientific world view (non absoluteness)	12	***82***	6
5	scientific world view (tentativeness)	***76***	18	6
6	scientific world view (continuity)	***82***	18	0
7	scientific enterprise (contribution)	0	***100***	0
8	scientific enterprise (contribution)	***76***	12	12
9	scientific enterprise (variety)	***76***	12	12
10	scientific enterprise (discrimination)	***35***	24	41
11	scientific enterprise (discrimination)	***59***	12	29

*thick, italic note means an acceptable answer
** T: true, F: false, N: I don't know

Discussion

We have found that gifted students possess quite acceptable NOS view of scientific world view and of scientific inquiry. They appeared to know that scientific knowledge is the subject to modification and tentative. They also seemed to be well aware of the role of hypothesis in scientific investigation as well as the possibility of bias and prejudice. In many ways, they showed that they have fairly adequate understanding about scientific inquiry. They also showed to have acceptable views of scientific enterprise, especially of contribution in science and of science ethics.

Nevertheless, we noticed that they have strong bias about discrimination toward the minority in science community. 70% of them admitted that there has been mistreatment toward the minority such as women, racial minority, and the disabled. However, when they were asked whether celebrities like Dr. Einstein or Madame Curie were mistreated in spite of their outstanding achievement, 85% of them answered that such people with prominent achievement were not affected by it. 11% of them answered that they do not know and only 4% of them gave correct answer. Non-gifted students also showed similar pattern in their answers. This result suggests that students admit the existence of discrimination toward the minority, but they accept this as an individual issue rather than accepting it as a social issue, and they believe if one is outstanding, he/she can overcome such obstacles. This tendency is stronger in gifted students because 85% of them possess misunderstanding, while 64% of non-gifted students possess misunderstanding. This is an interesting tendency and seems to be based on our school science education, but definitely required more studies to prove.

By comparing the result of gifted students to that of non-gifted students, we found that gifted students possess more acceptable NOS views. For each item asking various NOS idea, higher percentage of gifted students used to give acceptable answer. Table 4 shows the difference between two groups. Concerning scientific enterprise, gifted students showed better understanding except for the discrimination issue. What causes such difference between gifted students and non-gifted students are not clear, however, it seems to relate to the characteristics of scientifically gifted students. They usually possess better problem-solving ability in science and strong motivation toward science (Heller, 2002). They also used to make better achievement in school science. These factors could contribute to probe and to contemplate more deeply in science and it could result in having more informed view of NOS.

Table 4. The Percentage (%) of acceptable answer from gifted and non-gifted students

no	idea	gifted	non-gifted
1	Scientific World View (non absoluteness)	70	30
2	Scientific Inquiry (hypothesis)	75	40
3	Scientific World View (tentativeness)	96	73
4	Scientific World View (continuity)	94	69
5	Scientific World View (limitation)	83	75.5
6	Scientific World View (limitation)	53	56
7	Scientific World View (limitation)	85	65
8	Scientific inquiry (variety)	92	79
9	Scientific inquiry (process)	92	65
10	Scientific inquiry (controlling)	90	55
11	Scientific inquiry (bias & prejudice)	74.5	56
12	Scientific inquiry (bias & prejudice)	72.5	54
13	Scientific inquiry (bias & prejudice)	81	60
14	Scientific inquiry (bias & prejudice)	62	51
15	Scientific inquiry (bias & prejudice)	81	61
16	Scientific inquiry (bias & prejudice)	66	60
17	Scientific Enterprise (contribution)	85	65
18	Scientific Enterprise (discrimination)	70	48
19	Scientific Enterprise (discrimination)	4	13
20	Scientific Enterprise (contribution)	70	42.5
21	Scientific Enterprise (contribution)	66	45
22	Scientific Enterprise (ethics)	96	83
23	Scientific Enterprise (ethics)	96	65
24	Scientific Enterprise (ethics)	75	61

To trace how gifted students' idea about NOS progress according to ages, the result of 8th grade gifted students was compared to that of younger gifted students. As mentioned above, 5th grade gifted students showed better understanding than 8th grade non-gifted students in the area of scientific world view. From this result, we can assume that gifted students form their acceptable NOS view in their early ages, especially in the area of scientific world view. For example, gifted students seemed to already understand the tentativeness in science at the time of 5th grade. This is an advanced view in their age. We obtained relatively lower percentage of acceptable answers in the area of scientific enterprise. They would develop their NOS view about scientific enterprise later, for the area of scientific enterprise requires more sophisticated understandings. The result in Table 1 indeed shows that they developed more sophisticated view at the time of 8th grade. It is possible that educational programs given to 5th and 8th grade gifted students results in this tendency. 5th grade gifted students who participated in this study had been involved in gifted science programs for more than two years. These programs are usually enhanced and enriched programs and it might help for students to form more informed NOS view. Moreover, if these programs offer contents concerning scientific world view first, and introduces scientific enterprise later, it is likely to be responsible for the tendency shown in this study. The programs that 8th grade gifted students had attended for four months are different from younger students' programs. Such difference could have affected students' NOS view. However, 8th grade students and 5th grade students who participated in this study could have many other different aspects that might affect the result, therefore it is too early to make any haste judgement.

Conclusion

We have obtained following conclusions from this study.

First, we found that gifted students possess fairly informed or acceptable view of NOS. They understood NOS conceptions concerning scientific world view and scientific inquiry positively well. Their understanding of NOS surpassed that of ordinary, non-gifted students in many aspects and this informed understanding seems to be related to their giftedness in science. We concluded that the scientifically gifted students have equally gifted/informed view of NOS and it implies that adequate NOS view might be required to bloom scientifical ability to successful achievement. Therefore, we suggest that science education for scientifically gifted students should include NOS contents

Second, we discovered that scientifically gifted students formed their informed NOS view in their early ages, advanced to others. And they developed their NOS view to more sophisticated level as they grow, from conceptions of scientific world view to conceptions of scientific enterprise. It suggests that our NOS education for the scientifically gifted students should be based on such progresses.

There still are many unsolved, unclear problems that require further studies. For that purpose, we believe that our finding could provide a piece of information to further studies and could contribute to both science education and gifted education.

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Appendix

Test Items for 8th grade students

1. When similar investigations give different results, the scientific challenge is to remove all the differences to get exactly the same results.
2. Hypotheses can not be valuable until they turn out to be true, even though they lead to fruitful investigations.
3. Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.
4. Some scientific knowledge is very old and yet is still applicable today.
5. Some matters can not be examined usefully in a scientific way because they can not be tested objectively by their nature.
6. Any belief, including the existence of supernatural powers or the true purpose of life, can be proved or disproved in a scientific way
7. Science can be used to establish that some action is either moral or immoral.
8. Scientists differ greatly in what fact they study and how they go about their work.
9. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the

collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.

10. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but collaboration among investigators can often lead to research designs that are able to deal with such situations.
11. What people expect to observe often affects what they actually do observe.
12. Sometimes people invent a general rule to explain how something works by summarizing observations. But people tend to overgeneralize, formulating general rules on the basis of only a few observations.
13. Strong beliefs about what should happen in particular circumstances can prevent people from detecting other results.
14. Attending closely to any one input of information usually enhances the ability to attend to others at the same time.
15. Scientists know about the danger to objectivity and take steps to try and avoid it when designing investigations and examining data.
16. Scientists want to know the possible sources of bias and how bias is likely to influence evidence.
17. Important contributions to the advancement of science, mathematics, and technology have been made by European cultures only.
18. Until recently, women and racial minorities, because of restrictions on their education and employment opportunities, were essentially left out of much of the formal work of the science establishment.
19. Until recently, a few remarkable women and racial minorities who overcame obstacles were likely to have their work regarded highly by the science establishment.
20. No matter who does science and mathematics or invents things, or when or where they do it, the knowledge and technology that result rarely becomes available to everyone in the world.
21. Scientists are employed by colleges and government agencies. Their places of work are limited to laboratories and classrooms.
22. In research involving human subjects, the ethics of science require that potential subjects should be fully informed about the risks and benefits associated with the research and of their right to refuse to participate.
23. Biotechnology has contributed to health improvement in many ways, but its cost and application have led to a variety of controversial social and ethical issues.
24. Accurate record-keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.

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