Gifted girls and non-mathematical aspirations: A longitudinal case study of two gifted Korean girls

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Abstract

In this longitudinal study of two gifted Korean girls, experiences with early admittance into a gifted program are charted alongside their family and societal experiences which ultimately influenced their career choices in non-mathematical fields. The 8-year long qualitative study involved extensive interviews with the two gifted girls and their parents to determine factors that led to their choice of a non mathematical area of specialization in spite of early identification and support of their mathematical talent. Using tenets of qualitative inquiry to code the longitudinal data, we identified three main factors that contributed to these career choices, which are presented in the form of narratives. One of the startling findings of this study, contrary to the literature in gifted education research, is that the two girls' early experiences with gifted education kept them from choosing careers related to mathematics. The article also narrates the enculturation of mathematically gifted girls in Korea which leads to non-mathematical career aspirations.

Keywords: career aspirations; early identification; enculturation; gender inequalities; gifted education, Korea, mathematics, self-concept.

Introduction

It has been widely reported that the number of girls identified as being mathematically gifted (or enrolled in gifted programs) and the proportion of women in mathematics-related careers is significantly lower than those of boys and men. Despite many studies of these phenomena, participation of gifted female students in postgraduate courses in math or in related career fields still remains relatively very low compared to their male counterparts (Herzig, 2004,

2010; Mendick, 2005; Oakes, 1990; Stage & Maple, 1996; Stoeger, 2004). Unlike their Western counterparts, in Asian countries studies on the low rate of girls in gifted programs and process of their career choices, especially the under-representation of women in math-related professions have been rarely conducted. Korean students showed high achievements in the Third International Mathematics and Science Study (TIMSS) and the Programme for International Students Assessment (PISA), and the percentage of upper ranking students is also high compared to other countries (See OECD, 2004; Mullis, Martin, Gonzalez, & Chrostowski, 2004). However, the under-representation of girls in gifted programs has been continuously reported in Korea. According to Jung, Choi, Yoon, and Lee (2006), only 26% of students registered in out-of-school programs run by the gifted center attached to the universities are girls. Korea Science Academy, which is a senior-high school, especially for the gifted in mathematics and science, also shows severe under-representation of girls as can be seen in Table 1 (retrieved from the school homepage http://www.ksa.hs.kr/).

Table 1. Number of students in Korea Science Academy by gender

	10th	11th	12th
Male	132	132	133
Female	29	8	9
Total	161	140	142

In spite of high enthusiasm for education, national attention and support for gifted education (Park, 2004), Korea has steadily shown large gender differences in gifted population. This is the impetus of the research reported in this article, namely possible reasons for the aforementioned gender differences. This study explores factors influencing mathematically gifted girls' career choices. It does so by observing longitudinally the process that led two girls, identified gifted as 11-year-olds and who participated in gifted programs, gave up

careers in mathematics and related fields. The study also discusses ways to help gifted female students stay in gifted programs and pursue mathematics or related career fields.

Theoretical background

Over the past three decades, in a number of countries, particularly in developed countries, many researchers have attempted to not only uncover factors influencing gender differences in favor of males in mathematics but also reach gender equality in mathematics education (Fennema, 2000; Leder, 1992, 2010). Through this effort, gender difference in mathematics achievement have either decreased or are “on the way to disappearing” (Hanna, 2003, p. 6). In fact, in the UK and Australia, female students are achieving on par with their male counterparts or even better in most academic subjects including mathematics and this trend is also true for gifted population (Freeman, 2004; Gill, Mills, Franzway, & Sharp, 2008). In Germany, however, Preckel, Goetz, Pekrun, and Kleine (2008) reported that while no gender difference arose in teacher-assigned grades, male students achieved significantly higher scores on the German Cognitive Abilities Test, and this gender difference was more pronounced in gifted students than in average-ability students.

Freeman (2004) pointed out that patterns of gender differences were quite different between the UK and the USA. That is, in the USA, although gender gaps in mathematics achievement were generally becoming smaller, the superiority of boys over girls still existed in the gifted population. This gender difference in gifted samples was most evident in participation rates in gifted programs (Callahan, 1980; Fox & Richmond, 1979; Read, 1991) and in achievement on the mathematics part of the Scholastic Assessment Test (SAT-M), which identifies academically gifted students (Rebhorn & Miles, 1999).

In the case of Korea, where significant gender difference in favor of males has been proven from international assessments such as TIMSS and PISA, there has been a dramatic decrease

in the gap over the past decade: from a 17-score point gap in TIMSS 1995 to a 5-point gap in 2003; from a 27-point gap in PISA 2000 to a 9-point gap in 2006. However, gender differences in high-achieving groups, has by and large remained constant (Jung et al., 2007). From analysis of these inconsistent results in gifted students worldwide, Freeman (2004) asserted that cultural differences such as gender expectations and gender role-models may exert a strong influence on the status quo. Within the mathematics community, a very noticeable aspect of skewed gender distribution among the highly gifted is in the International Mathematics Olympiads. Even in the so- called progressive countries where the achievement gap between males and females has been steadily decreasing, the 6 member teams from these countries are predominantly male. For instance, in the 47th IMO held in 2006, teams of six contestants each from the U.S.A, Australia, Germany, and Finland consisted of 6 males and 0 females. Even the team from Iceland, a country which showed remarkable *gender differences* in PISA 2003 in favor of females, consisted of 6 males and 0 females (Sriraman, 2008). Moreover in the U.S.A, the National Science foundation reported that only 12% of tenure-track faculty in mathematics departments were female (NSF, 2008). These startling statistics confirm many of the research findings that gender differences among the gifted population are more pronounced than in the average ability population, particularly at the tertiary levels where career choices are made.

Although there has been improvement toward gender equality in mathematics performances in the general population, gender inequality in gifted samples is still a concern for many researchers. Furthermore, under-representation of gifted women in career fields related to mathematics, natural sciences, and technology is also problematic in most countries around the world (Stoeger, 2004; Blickenstaff, 2005; Hollinger & Fleming, 1992; Lubinski, Benbow, Shea, & Eftekhari-Sanjani, 2001; Gill et al., 2008). The question is why does low participation of women in math and science careers continue despite the efforts for gender

equity? And more importantly, why do gifted women in mathematics still avoid choosing careers in those fields? Many studies have tried to answer these questions since the 1980s, and the explanations include two different views: ability differences between the genders; social influences such as socialization and gender roles (Hollinger & Fleming, 1992; Preckel et al. 2008; Hargreaves et al. 2008). Now, many researchers assert that ability differences alone cannot explain women's career choices of not choosing math and related fields, although these differences cannot be ignored completely. This means social influences and related psychological factors such as self-confidence and interests more effectively explain the phenomena (Blickenstaff, 2005; Brandell & Staberg, 2008; Hargreaves et al. 2008; Spelke, 2005; Steinthorsdottir & Sriraman, 2008). In the next section, some studies on psychological and social factors influencing the under-representation of gifted women in math and related areas are reviewed briefly.

Psychological factors

Gill et al. (2008) and Ivie, Czujko, and Stowe (2002), interviewed women engineers in Australia and surveyed women physicists from over 50 countries around the world respectively. They reported that women's strong confidence in their mathematical abilities was an important factor not only in their choice of these particular occupations but also to endure male-dominated institutional circumstances.

In spite of the importance of confidence in females to pursue math and science careers, many studies have reported that gifted females as opposed to gifted males tend to show less positive attitudes toward mathematics, as well as lower confidence and interests. In fact, Schober et al. (2004) found that 10th grade gifted girls in Germany presented a lower math self-concept than their male counterparts, and their math self-concept was a strong indicator of subject selection for the major exams (gifted girls tended not to choose natural science subjects). In a more recent study with a gifted sample conducted by Hargreaves et al. (2008), gifted girls

between the ages 9 and 13 were less confident in their mathematical abilities than gifted boys although they performed better than the boys in a math test. The gifted boys, in addition, displayed more positive attitudes towards math than the girls, and the differences were more significant for the 13-year-olds than the 9-year-olds. Preckel et al. (2008) also investigated gender differences in math-related self-concept, interest, and motivation, specifically through the comparisons between gifted and average-ability groups in grade 6. In their study, females in both groups showed lower self-concept, interest, and motivation in mathematics than their male counterparts, and these differences were more pronounced in the gifted group than the general group. These relatively low, math-related affective variables pertaining to gifted girls may negatively impact their major selections in math and science related areas in college, and consequently, many gifted women are lost in tertiary fields (Junge & Dretzke, 1995; Preckel et al., 2008).

While many studies have still reported gender differences in favor of boys in math self-concept and attitudes, some studies assert that girls including gifted girls are not disadvantageous anymore compared to their male counterparts by not only improving their achievements but also changing their attitudes toward math positively (Freeman, 2004; Forgasz, Leder, & Thomas, 2003; Schober et al. 2004). These inconsistent results, according to Freeman (2004), may have a cultural basis. Therefore, in the case of Korea, it is important to investigate how gifted girls perceive their mathematical abilities and how these perceptions influence their career decision making process.

Social factors

Gender stereotypes of mathematics: There is a general belief in most societies that mathematics is a masculine subject and careers related to math are male domains. Many studies on gender stereotypes about mathematics have consistently documented that girls as well as boys perceive mathematics as a male domain. This gender biased view may be

influenced by a society showing a strongly gendered workforce (Brandell & Staberg, 2008, p.498; Steinthorsdottir & Sriraman, 2008). More problematic situations are that these gendered views can be found among gifted female students despite their mathematical talent (Mendick, 2005), and older students, who may be on the career decision making process, tend to have these views more strongly than younger students (Brandell & Staberg, 2008). In Mendick's study, gifted females perceived that males were better at math than females and math was a male domain, so they believed that they were poor at math and were more inclined to deny their math abilities. These beliefs may make gifted girls overly concerned and feel the burden of harder work than gifted males (Brandell & Staberg, 2008), and consequently may lead the girls to avoid studying math continuously and choosing math related careers.

The gender perceptions about math, furthermore, can cause difficulties for women as a minority group when studying math or working in math fields. Gill et al. (2008) and Herzig (2004, 2010), in fact, from their qualitative studies of professional women engineers and women majoring in math, discovered that women perceived a male-dominated culture in their workplaces and universities, and had difficulties in feeling a sense of belonging due to a sense of alienation and less support for women. Furthermore, female students who were not integrated with the male-dominated learning environments had a strong tendency of giving up a Masters or a Ph.D in math (Herzig, 2010).

As can be seen from our summary, gender stereotypical views about math are prevalent in young students groups as well as across society. These gendered views may not only negatively affect gifted girls choosing math careers but also inhibit the gifted minority of females majoring in math from studying further.

Parental influences: Many studies have asserted that despite the importance of parent's role in supporting their children's mathematics learning, parents are inclined to treat their

daughters and sons differently, and it might cause gender differences in favor of males in mathematics (Bhanot & Javanovic, 2005; Geist & King, 2008; Jacobss & Bleeker, 2004). The importance of parents has been emphasized for gifted as well as average-ability students. This is because parents tend to recognize early their children's gift and can provide appropriate support and encouragement to develop the children's gift (Ivie et al., 2002). However, although parents expect good grades in all school subjects including math and science, when it comes to their gifted daughters, they tend not to consider careers related to math (Noble, 1989, cited in Schober et al., 2004, p.45). This parental tendency, therefore, may hinder gifted girls from developing their full potential, despite their mathematical abilities. For gifted girls to reach their mathematical potential fully, Read (1991) asserted that parents should support their daughters to remain in gifted programs and encourage their daughters' achievements and interests in non-traditional areas, and also need to advise them in choosing careers in those areas (Fox & Richmond, 1979).

In some studies on women working or studying in math and science fields, the women commonly mentioned the importance of their parents, particularly their fathers, in their course and career selections (Ivie et al., 2002; Sonnert, 2009; Stage & Maple, 1996). Their fathers played a critical role in stimulating their mathematical and scientific interests and in providing information about such careers.

Jacobs and Bleeker (2004) and Bleeker and Jacobs (2004), on the other hand, emphasized, through their longitudinal studies, the importance of mothers in their children's interests in math and science and children's career selections. That is, Jacobs and Bleeker (2004) found that mothers' proactive behaviors including purchases of math and science items and activities strongly influenced their children's later interests and involvement in math and science. Bleeker and Jacobs (2004) also reported that mothers' gender stereotypic belief in their children's abilities to succeed in math and science related careers, in favor of boys,

negatively affected their daughters' confidence in math and science as well as career choices in those fields.

Oakes (1990) pointed out, in her review of research on parental influences, that if parents' educational levels were higher, girls tended to make more career choices in fields related to math and the natural sciences because these parents did not force conventional gender roles on their daughters and also encouraged them to pursue nontraditional female careers. More female students than males may be more strongly influenced by their parents in shaping their attitudes toward math and making career decisions (Sonnert, 2009). Therefore, more studies on how parents' beliefs and views are conveyed to their children are needed. In addition, to increasing gifted girls' and women's participation in the fields of math and the natural science, intervention programs for parents should be actively used to eliminate their gender stereotypic beliefs.

The study

Our objective as to describe, analyze and explain the main factors contributing to two mathematically gifted girls' career choices, Kim and Lee (pseudonym). The two girls were chosen explicitly to study and to understand "the causal links in real-life interventions that are too complex for the survey or experimental strategies." (Yin, 1984, p. 25) Kim and Lee were identified as gifted when they were 11 years old (5^{th} grade) through a talent identification program, involving a three stage process that assessed: (1) creativity and logical thinking ability, (2) mathematical knowledge and skills, and (3) mathematical thinking ability and attitude toward mathematics and mathematics learning. At the time of the identification of the students as gifted, they showed not only superior mathematical problem solving skills (within 5% of the applicants) but also positive attitudes toward mathematics (within 5% of the applicants). They had participated in a special out of school program for the gifted for two

years with thirty other male gifted students identified by the same process. Both girls agreed to participate in the study. Thus, we made a choice to observe both rather than one of the two. The thirty-two students including the two girls for this study were educated in two separate classes, 16 students were in each class, and the two girls were in the same class. The educational program was constructed by professors in the university to develop students' mathematical thinking, and more than 86% of the class teachers were males. When the students started the program at the center of gifted education more than 95% of the students were aspiring for careers in natural science and engineering, and the two girls also expressed the same idea. This study investigated, through long-term interviews, reasons why the two girls wanted to pursue natural science, and why they eventually *did not* choose natural science majors in university.

The researchers hypothesized that parental influences might be critical for the two girls to choose their careers. Therefore, when the girls were in 6th grade and 10th grade, the parents of the two girls were interviewed twice for one hour each (hereafter referred to as PRKIM6, PRKIM10, PRLEE6, PRLEE10). Kim's father was a university professor and her mother was a high school teacher. Both parents were humanities and sociology majors and had the opinion that studying natural sciences and engineering were difficult for female students. Lee's parents also majored in humanities and sociology, her father worked for the government and her mother was a housewife. Lee's parents also expressed that careers related to natural science were difficult for women. When the girls were in grade 6, in the first parents interviews, the girls' parents said that they would consider their daughter's participation in natural science and engineering, if the daughters wanted to do so, because their daughters liked mathematics so much. In the second parents interviews conducted when the girls were in grade 10, however, both of the parents said that they did not want their

daughters to major in natural science and engineering. These parents' views were analyzed by comparing them with the views expressed by their daughters'.

Interviews with the two girls were conducted at regular intervals over a longitudinal period: three times when they were in grade 5 (March, June, and December, referred to as KIM5-MAR, JUN, DEC and LEE5-MAR, JUN, DEC)[1]; twice in grade 6 (June and December); twice in grade 8 (June and December); twice in grade 10 (June and December); twice in grade 12 (June and December); once after entering university (March, to referred as KIM_COLLEGE, LEE_COLLEGE). Each interview was conducted for 1-2 hours informally focusing on their intended career path and factors that influenced their career choices. The interviews were recorded and transcribed, coded and analyzed for factors influencing career choices. We followed the constant comparative method of data analysis (Corbin & Strauss, 1998) consisting of: (1) open coding, (2) axial coding, and (3) selective coding (Creswell, 1998, p. 57) to find the factors influencing the two girls' career choices. Given that the study was qualitative in nature, the transcripts were analyzed according to the basic tenets of qualitative inquiry (Bogdan & Biklen, 2006; Patton, 2002) with careful attention given to inter rater reliability in the independent coding (Rubin and Babbie, 1997) done by the authors and other research colleagues. There was agreement of over 90% in the coding of basic factors that affected career choices of the two gifted girls.

Analysis and findings

According to the results of analysis of the two girls' interviews, the factors affecting their career choices were classified as a triadic: mathematics learning experiences, parental advice, and recognition of gender inequalities in the society. In the following section, we report on

[1] Readers should note that an academic year in South Korea begins in March and finishes in December

how the girls recognized these three factors and how the factors influenced their career choices. The findings are conveyed in the form of narratives with a thick description of the major events unfolding in the lives of the two individuals (Clandinin & Connelly, 2000). The focus on two specific girls limits us in the scope of inference. However by virtue of the longitudinal nature of the study, the themes emerging from the data are consistent and of value to the community. The vignettes, with the coding scheme presented in this section, is representative of the emergent themes from the qualitative data.

The reasons for Kim's choice not to major in natural science

Kim had changed her intended career from a mathematician (5th grade), a scientist (6th grade and 8th grade), and a diplomat (10th grade) to a diplomat or a simultaneous interpreter (university). Although Kim had worked very hard at mathematics to be a mathematician at the time of participating in the program for gifted, she did not eventually choose natural science as a major. Therefore, the reasons why Kim changed her career path were examined according to the three factors.

Kim's mathematics learning experiences: Kim wanted to be a mathematician in 5th grade and expressed that mathematics was interesting because it was like games or puzzles. She explained, “There may be rules used only in mathematical world” when she was interviewed in 5th grade. She described her mathematical problem solving process as finding rules and decoding. The following comment excerpted from her interview data shows her joyful feeling when solving mathematics problems.

> If I solve math problems I feel better even when I am in a bad mood. I really love mathematics. If I say this feeling to my mom, she says that it is difficult for her to understand my feeling (KIM5-MAR).

Her interest in mathematics had dramatically changed while preparing for math competitions in grade 6. A critical reason for the change in her attitudes toward math was that she had to learn new strategies for solving problems rather than applying rules. She was involved in a preparatory class for math competitions in a private institute. She reported she solved mathematics problems for 2 hours daily in the class and have to solve more problems at break times in school because of lots of homework from the preparatory class. This experience made her feel that mathematics was difficult. She felt a difficulty dealing with complex problems and complained she did not even know what the problems were. She admired a few boys studying mathematics with her at their excellence in mathematical problem solving.

Kim had been gradually losing confidence in her mathematical abilities. She was quiet at the center of gifted education and expressed her opinions only if she was given a chance for a presentation. Her mathematics learning experiences in a preparation program for mathematics competition led her to negative self-esteem in her mathematical abilities. She explicitly mentioned, “mathematics seems to be for special persons. I am normal” in the interview (KIM6-DEC). She described her mathematics learning as “a level of understanding, i.e., a student” and one boy’s as “a level of discovering, i.e., a mathematician” in the same interview. She doubted and degraded her mathematical talent from her 6th grade.

When Kim was in grade 8 and grade 10 she still believed that mathematics was for an especially talented person, therefore, she decided to enter the school of humanities, not the school of natural science at the end of grade 10. She described her excellence in mathematics as just an advantage she got from her mathematics learning experience in gifted programs.

She was happy with a good grade in mathematics with less effort than other students. She took her top grade in mathematics for granted and claimed she still liked mathematics. However, she declared she gave up the ambition of becoming a mathematician or a scientist in her 10^{th} grade.

> Mathematics class in school is more fun than the other classes. I am the best in mathematics in our school, so my teacher often let me explain how to solve mathematical problems to the other classmates (KIM8-DEC).

Parental influences: When Kim was in grade 6, Kim's mother said that she was not yet convinced of her daughter's mathematical talent. Her mother also expressed that she was willing to allow her daughter to major in natural science or engineering if the daughter had "sufficient" mathematical talent.

> Yet, Kim is just better in math than normal students. She must be watched more. It is too early to decide. But, isn't it so hard to enter fields related to natural science or engineering? How about you? Frankly, if women in our country are to succeed, they should be supported by their family. I think, it may be really hard to compete with men because there are few women in natural science and engineering fields. Becoming a professor is okay, but otherwise it should be hard to work as a researcher or an officer worker. It will be better now not to make any decision (PRKIM6)

Kim's father said that he also deferred a decision about his daughter's career path with an open mind. He was also good at math in school, but when the time for a decision on his career came, liking history and social studies influenced his career decision more than in math.

> I did well only within mathematical contents given to me, but history and social studies were really interesting. I felt an academic attraction from those subjects. I don't know yet whether my daughter is good at math or likes it. She seems to like math, but I should wait more and watch her carefully. If she wants to do natural science or engineering I won't stop her, but I should check if she really likes those subjects. Otherwise she may be in trouble and regret it in the future. Anyway, I can't say anything yet (PRKIM6)

When Kim was in grade 10, Kim's mother said that her daughter liked English and Social studies more than mathematics. The mother also stated that it might be better to get her daughter to major in Humanities and Social studies rather than suffer from solving math problems because of her daughter's superior writing skills.

> Yes, She is good at math. Still she is doing very well, so I am happy with that. Other moms really worry because their daughters are poor at math, but I feel comfortable. But, Kim is really good at English and likes it. Her teacher says that she is superior at social studies as well. I don't yet discuss this with my daughter, but I just think that becoming a diplomat or a sociologist... or a counselor with a major in psychology may be suitable for her (PRKIM10).

Lack of mentors and recognition of gender inequality in the society: Kim expressed her pleasure in the interviews for this study because she felt comfortable with the female interviewer (the first author). Most of teachers she had met from the center of gifted education as well as the private institute were men.

> Were you (interviewer) really good at math? Why did you continue to study math? Any females from my family didn't major in math or science, so you look weird to me. And, I think you are really cool. But, I am getting to like other subjects than math, like the other family members. How can one do well in math continuously? Did you study a lot of math everyday? (KIM6-DEC)

The following interview (in grade 8) indicated that Kim still could not find a mentor around her. She also started to have specific interest in her career choice.

> If I continue to study math, what jobs can I get? My aunt majored in English literature, and she liked being a teacher so she became a teacher. My cousin sister is also studying to be an elementary school teacher. I think, becoming a teacher isn't so bad and isn't so good either. My aunt told me that there was gender equality in teacher community but male dominance in other career fields. But there are only few female principals. So, I think it isn't so equitable either. My mom gave up her studies further after meeting my dad, but I want to continue studying after marriage. I think women's lives are very complex (KIM8-JUN).

Kim had already decided her career path at the end of grade 12 and seemed very happy. She also pleasantly remembered being recognized as mathematically gifted in elementary school.

> Being good at math gave me a lot of confidence. I think that I wasn't genuinely gifted in math, but it was really good to be treated as a genius by everyone around me because I did well in math. But, it was also a lot of pressure on me. Now I can do things I like, and I don't need to pay attention because there are many women in this career field. I

> felt discomfort and found it hard among many boys, but now I am really happy because I don't need to be nervous about that any more (KIM12-DEC).

Kim who became a college student looked full of confidence with expectations for the future.

> I want to be a diplomat. I have believed that I liked more English than math since middle school, so I am so happy to think of English. If I become a diplomat or a simultaneous interpreter I can travel overseas a lot...and it should be very good. Myung-Kyu entered the school of math. It is good for him. I think that I liked math more and was better than him when in grade 5...but in retrospect, I think that students who just concentrate on solving math problems without distracting thoughts are really good at math, like Myung-Kyu (KIM-COLLEGE).

The reasons for Lee's choice of not majoring in natural science

Lee had changed her career path from a scientist (5th grade), a biologist (6th grade), and a social worker (8th and 10th grade) to a sociologist (university). Lee, like Kim, was full of confidence and enthusiasm in math at the time she participated in the program for gifted, but she finally left the fields related to natural science or engineering. The reasons for her leaving were investigated in the light of the three factors and reported in narrative form as in the case of Kim.

Lee's mathematics learning experiences: Lee presented that she wanted to be a scientist when she was in grade 5, and the reason for that was science could be of benefit to mankind.

> I think science benefits mankind. So, if I become a scientist, I can do famous experiments and also develop theories, then I can popularize my country, I have a big dream. My dad told me that to study math hard could help me when I become a scientist, so I am

> studying hard now. I have studied math with three boys since 3rd grade (in a private institute). We have dealt with many difficult math problems, I got praised that I did well in my homework and also study harder than the other boys. The teacher is more scary than my school teacher (LEE5-JUN).

Lee also had solved many problems in order to prepare for math competitions while she was in grade 6. Lee was still very good at math, and she got the 3rd place in a national math competition so she had great expectations.

> No kidding. There was such a lengthy problem, more than seven lines, and it took a while, only to calculate. There was a problem that made me feel unbelievable I solved that. Anyway, I make a note of the wrong answers after solving problems, but most of the problems are in the note. I make one or two mistakes in calculations, and I think that making the note may be good for me because the solutions are odd. Of course, the boys don't do homework, and don't concentrate on a class, so the teacher said I am the best prospect. I have in mind to become a mathematician not a scientist (LEE6-DEC).

When meeting Lee again in grade 8, her attitudes had changed surprisingly. Lee had got praise from teachers of all subjects in her school.

> I am really busy. To get a good grade in performance assessments, I have to often stay up all night. The last time, I stayed up all night for Fine Arts, and I have to stay up tonight again to do Home Economics homework. Math is the easiest subject to get a good grade in performance assessment. I can get 'A'. I have normally organized my math notes, and if I add just one page to the homework, my teacher may be satisfied with that. But, I am

> getting more interested in English than math, and also beginning to like social studies and fine arts. When I went for volunteer activity at the church the last time, I was praised for playing the flute well. I think that I seem to be quite fit to go around and get along with people rather than stay in a lab quietly. So, I stopped preparing for math competitions. My parents didn't say anything about that and just leave me (LEE8-DEC).

Lee, like Kim, was very good at math in grade 10 as well as grade 12. However, she had decided to enter a college of liberal arts instead of a college of science.

> I think it is advantageous for me to do well in math. Because other students are really busy to attend a math institute. I miss math, but it seems preferable to leave math with my favorite subject. I feel really happy when teaching math problems to my friends. I liked studying math more than other subjects, but I'm not gifted so it's ok (LEE10-DEC).

Parental influences: Lee's father recognized her prodigious mathematical abilities when she was in grade 5. However, he did not want his daughter to choose fields in natural science and engineering.

> It's obvious she is good at math. But, if she chooses natural science and engineering, it may be very hard. To continue to study math may be okay, but if she majors in science, she has to be in a lab late nights. I guess, in the future, her husband or family won't allow her to do so, so I want to persuade her not to choose those majors. Lee has a younger brother, and he is also good at math so I definitely want him to be in natural science and engineering fields, but it's hard because Lee is a daughter (PRLEE6).

Lee's father had already persuaded her when she was in grade 8, providing information about careers such as a lawyer of a diplomat, not careers related to natural science and engineering.

> My dad is one of the most respected persons to me. So, I may obey my dad. I like math, but I also like English, social studies, and fine arts. So, maybe, I won't major in natural science and engineering as my dad said (LEE8-DEC).

Lee's mother perceived that her daughter, unlike her son, had a gift for English. She said in the interview that while her son only liked and was good at math and science, her daughter liked all subjects and was really interested in speaking and writing in English in particular, therefore, her daughter was not appropriate for natural science and engineering.

> She is doing well in all subjects in school, but she likes English in particular. I heard that she suggested making a school's English newspaper and made it. She was really enjoying it despite it taking a long time. I was a member of a mass communication club in my school days and she is also interested in it, so I can't think that she is suitable for natural science and engineering (PRLEE10).

Lack of mentors and recognition of gender inequality in the society: Lee stated (like Kim), she could not find any woman around her who was in field related to natural science or engineering. She had an aunt who was a dentist, but Lee said that she did not want to study medicine because it did not seem fit for her.

> There is no family member who worked in natural science or engineering fields. My aunt was studying in administrative studies, but she transferred to a dental college and became a dentist. But, she said she isn't happy. It's said that a job that can allow much free time is

> good for women, but I think that studying math or science means to spend a lot of time. Many people said that natural science and engineering should be hard for women (LEE6-DEC).

When Lee was in grade 8 she met a mentor who worked in sociology. She, therefore, became interested in those career fields.

> I thought that studying at the university was the best, like you. But, I felt that a social worker whom I met from the church was so cool. She said that our country's social welfare systems haven't been built well, having so much work to do but it's rewarding. It seems good to continue to study math, but I think that mathematicians should be apart from people, to study math in depth...but I love people (LEE8-JUN).

At the end of 8th grade, Lee recognized that Korean society is very traditional and has gender stereotyping.

> Why are there few women politicians? Why can't women take an important position? I heard there is sexual discrimination in companies, and too many things are unfair for women. My parents are more interested in my younger brother than me, and my relatives are also more concerned about my brother's future than mine. Why is there severe discrimination against women in our country? Is there no sexual discrimination in university? (LEE8-DEC).

Lee seemed to be adamant in her determination to be in sociology in grade 10 and university as well.

> I want to be a sociologist. I want to give a small seed of hope to many people in the world who are discriminated against. I think that while men are gifted with logical skills, women are gifted with sensibility. I think that Math has been developed by logical skills and sociology has been developed by sensibility. I liked math, but I don't think math is suitable for women for all ages because there are only few female mathematicians. I

looked up on a website of math faculty, but professors are mostly men. I want to study fields that can meet many people rather than math or science (LEE-COLLEGE).

Discussion and conclusion

In this section we establish validity of the findings by using "triangulation by theory"—i.e., application of various explanations from the theoretical background to the findings at hand and the selection of the most plausible ones to explain the research results (Bogdan & Biklen, 2006). The purpose of doing so is to establish the validity of the findings in relation to previous findings, as well as to distill findings that do not cohere with what is presently known in the canonical literature. In this study, the two gifted girls remembered attending the center of gifted education and being better at math than their peers throughout their schooldays as positive experiences. When choosing majors, however, they judged themselves lacking in math talent due to their mathematics learning experiences, particularly the experiences for developing their math abilities, such as participating in a private institute and solving math problems requiring high cognitive skills. This finding indicates that gifted education based on national support, ironically, can hinder gifted girls from selecting careers in natural science and engineering.

Callahan (1980) pointed out that gifted girls could refuse to participate in gifted programs because the programs were not interesting for them. As she pointed out, from the fact that the two girls dropped out of gifted programs, we can presume that contents of gifted programs alone are insufficient to arouse their interest in math. Besides equality of opportunity for gifted education, there is a need to develop and implement gifted programs considering gifted girls' characteristics and educational needs (Read, 1991).

The two girls studied math more than their peers did until grade 7, but spent less time since the end of junior high school. They thought that their participation in gifted education early

on reduced the pressure of math study, and eventually it helped them enter university. It is very different from the primary aim of gifted education, which is "discovery and development of gifts". Contrary to Fox and Richmond (1979)' claim, which is that early identification and education may be beneficial for gifted female students, the two girls' early experiences of gifted education kept them from choosing careers related to math. Therefore, it is desirable that parents, who hope their daughters select careers in natural science or engineering, decide their daughters' participation in gifted education after considering whether or not the program's content and the model are appropriate for their daughters.

Many researchers have paid attention to female students' low participation rate in gifted programs at higher grades (Callahan, 1980; Fox & Richmond, 1979; Read, 1991). Read (1991), for instance, found a significant decrease in the number of girls in gifted programs from grade 10 to 12 and mentioned peer pressure as a critical factor discouraging girls' participation in gifted programs. However, the girls who took part in this study felt a great burden from their parents' and school teachers' high expectations for them. The girls seemed to refuse to participate in gifted programs since grade 8 because of the dissonance between high expectations of parents and teachers for their math talent and their judgment about a lack of their abilities while attending gifted programs. This result indicates that gifted girls may feel more pressure than gifted boys of meeting expectations of adults around them, and it can discourage continuous participation of girls in gifted education and also negatively affect their career choices in math and related fields. Therefore, it would be better to guide gifted girls not to only obsess about visible outcomes during participating in gifted programs.

As can be seen in the results, although Kim had liked math very much from childhood, she was frustrated at being unable to cope with the process of finding strategies for a lot of math problems in a private institute. It seemed stressful for her to find various problem-solving strategies before understanding problems. It may be helpful for girls like Kim to be taught

that problem-solving strategies can be found through continuous improvement of incomplete ideas via many trials and errors. Therefore, gifted programs for female students should endeavor to inform them on the role of incomplete ideas or trial and error, and intervention programs should also be developed to en-culturate them to the fact that even many mathematicians acquire mathematical knowledge through the same process. It is plausible that gifted girls, especially, may need to be educated in a single-sex class rather than a mixed class to share their ideas easily and experience less hurt of their feelings even if they make mistakes. Therefore, as Callahan (1980), Fox and Richmond (1979), and Reid and Roberts (2006) mentioned, it can be more effective for gifted female students to be educated in a single-sex classroom using cooperative activities and female role models.

As many previous studies reported (Bleeker & Jacobs, 2004; Ivie et al., 2002; Jacobs & Bleeker, 2004; Sonnert, 2009; Stage & Maple, 1996), the parents in this study seemed to be a critical factor influencing career choices of the two girls. However, contrary to the findings of Bleeker and Jacobs (2004) and Jacobs and Bleeker (2004), which emphasized the importance of mothers, the girls in this study were influenced more by their fathers. When the girls were in elementary school, both fathers stressed that if the two girls wanted to major in math or related areas, they should be good at math and like math very much as well. Their fathers' view worked like invisible standards measuring their talent in math while they were growing. While participating in gifted programs, the two girls experienced frustration due to their perceived lack of ability compared to their male counterparts, but experienced outstanding achievements in humanities subjects such as social studies and English. These experiences made them believe that while male students had more talent in math, they had more talent in humanities, so they tended to deny their potential mathematical abilities due to relatively lower math self-concept (Mendick, 2005). Female students' tendency to like and do well in all school subjects (Callahan, 1980; Fox & Richmond, 1979) and their diligent attitude to

homework from school teachers (Brandell & Staberg, 2008), which are unlike male students' tendency to focus on a certain subject they like. This seems to catalyze the thought of them liking and being good at other subjects than math. Therefore, the fathers' standards of career choices, which was "should like and be good at math to select math careers", seemed to make the two girls focus on remarkable achievements in other subjects rather than math, consequently it was a critical factor for the girls in abandoning careers in the mathematical realm.

While participating in gifted programs, the two girls perceived gender inequality in the society. Especially, they noticed that while there were only few women professors and researchers in fields related to math, there were relatively higher proportion of women in humanities and sociology fields. They believed that it was difficult for them to choose math careers because of clear gender inequality in those occupations. Because the interviewer was female for this study, the girls asked several times if it was hard to live as a woman in math areas. This suggests that gifted female students need to be informed how to balance between women's lives and academic achievements in fields related to math and science. It also needs to help gifted girls perceive how women's achievements contribute to those fields and the society and how work environments are changing now. Finally, limitations of this study and recommendations for further study are discussed in the following section.

Limitations and Recommendations

Firstly, two gifted girls were selected for this study to trace the process of mathematically gifted girls' career choices in Korea. We observed that the two girls abandoned careers in math area after grade 8 and consequently majored in humanities and sociology fields in university. Furthermore, several factors influencing their career choices were found in this study. It may be difficult to conduct such longitudinal studies, because the number of gifted

girls participating in gifted programs is relatively very small in Korea. However, more gifted girls need to be observed in the long term to uncover factors encouraging or discouraging their career selections in math and related fields, so that appropriate counseling can be made available for gifted girls to stay in those fields.

Secondly, in this study, fathers' role in their daughters' math learning was indirect, but the two girls were influenced strongly by their fathers when choosing their careers. However, because this study focused on changes of two girls' perceptions, specific information about how the fathers guided their daughters' career path was lacking. Nevertheless, it was confirmed from this study that it might be hard for gifted girls to pursue math or related fields without changing their fathers' perception on daughters' career choices. This may very well be a cultural trait peculiar to Korea but is worth further investigation in other parts of the world. Therefore, the perception of fathers whose daughters are gifted in math needs to be analyzed in detail with more cases, and intervention programs to change fathers' perceptions are also needed in gifted education.

Lastly, the two girls perceived gender inequality in the society earlier than the researchers' expectation. They had been concerned about their future careers from elementary school, and perceived gender inequality since then. However, the girls showed vague fears about careers in math related areas and gender roles. In gifted education, more efforts are needed to alleviate gifted girls' vague fears by discussing non-traditional gender roles or by providing information about math-related careers through female role-models.

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