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Environmental and Interpersonal Factors on Development of the Mathematically Gifted: Cases of International Mathematical Olympiad Winners from Korea

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Spending as much time outside of school as in school, gifted youth are affected by non-school aspects including parents, other family members, peers, mentors, mathematics competitions and camp participations. These influences have been known to shape children's intellectual development, academic achievement, interests, and eventually college and career choices. From interviews with five former Olympians from Korea to identify out-of-school influences on their academic achievement and development, we discovered, in addition to confirmation of previously identified factors, additional sources of positive influence seldom previously mentioned and more common to Korean culture were gleaned - mathematics workbooks and Ha-Gwon. The findings of this study are informative for teachers and parents who are interested in development of gifted youth in providing ways to accommodate their special needs and in showing how they can carefully individualize those sources to be positively affecting intellectual development as well as academic achievement.

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I. INTRODUCTION

Numerous factors can be attributed to a student's academic success, many of which are unrelated to school. Students spend more time outside of school in a more informal

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context, learning from family, friends, peers, mentors, and out-of-school activities. Since there is no single formula to guide students to their fullest potential, it would be informative to examine many sources of influence to better understand how to accommodate the optimal environment to fully stimulate a student's motivation and potential (Choi, 2013; Muratori et al., 2006). Research also recognizes that one's psychological conditions attribute his or her education and development (Choi, 2010; Krutetskii, 1976).

II. LITERATURE REVIEW

Until a child displays high achievement or performance, their raw potential is unlikely to draw attention. Researchers recognize the difference between childhood precocity and domain-specific abilities and suggest explanations for a developmental path that unveils children's natural talents (Feldhusen, 1994; Gagne, 2004, 2005a, 2010; J. Piirto, 1999; Tannenbaum, 1983, 2003a). To connect and explain the developmental path, Feldhusen's Talent Identification and Development in Education (TIDE) model emphasizes specific abilities and supports further implementations of gifted programs that target specific domains of abilities. Gagne proposed a model to differentiate (natural) giftedness and (performed) talent and offers insights on influential factors (catalysts). Influential factors in Gagne's model are intrapersonal and environmental catalyst that facilitate or hinder a gifted individual's developmental process of translating their gifts into talents. Chance is another causal factor that Gagne included in his model; however, it is an element that could be placed in any other category. Feldhusen explicates five factors that link potential to performance, which must be in place to transform childhood giftedness into exceptional adult performance. The Pyramid of Talent Development that Piirto proposed also consists of five levels: genetic ground, emotional basis, cognitive ability, level of talent, and environmental level. The environmental level, which includes home, community and culture, school, gender and chance, is distinguished from the other four levels of Piirto's model that influence individuals from outside while the other four levels are personal or genetic aspects.

Well-known talent development models commonly signify **environmental influences and intrapersonal (psychological) conditions** of individuals in addition to general ability (i.e., genetic or innate aspects). Studies on environmental factors are exhaustive and they provided convincing evidence that environmental factors make significant contributions to the talent development of precocious youth. Many *persons* - family members (Bhanot & Jovanovic, 2005; Bloom, 1985; Campbell & Verna, 2007; Cox, Daniel, & Boston, 1985; Geist & King, 2008; Jacobs & Bleeker, 2004; Lee & Sriraman, 2012; Sonnert, 2009; Stewart, 2008), mentors and peers (Bloom, 1985; Clasen & Clasen, 1997; Kao, 2011; Marsh, Allen, Ho, Porter, & McFarland, 2006; Muratori et al., 2006; Peat, Daziel, & Grant, 2000; Ryan, 2001; Schapiro, Schneider, Shore, Margison, & Udvari, 2009; Wright & Borland, 1992; Zorman, 1993) are reported as influentially positive and negative. The educational *provisions*, including training programs and educational practices - competition experiences and out-of-school educational practices (Allenbaugh, 2002; Bell, 2010; Benson & Baroody, 2002; Ericsson & Charness, 1994; Ericsson, Krampe, & Tesch-Romer, 1993; Kim, 2008; Kwok, 2004; McKenna, Hollingworth, & Barnes, 2005; Pata, Lehtinen, & Sarapuu, 2006), are frequently and intensively discussed environmental factors involved in talent development. There are many *events*, both positive and negative, that significantly promote personal talent development in a specific domain including death of a close family member, winning an award, and suffering from a major accident or illness (Gagne, 2000; Olszewski-Kubilius, 2010).

Familial influences, such as reading at home, taking children to the library, reading to their children, and supporting their children's ideas have been shown to be positively correlated with a child's academic success (Cox et al., 1985; Haile & Nguyen, 2008). This type of positive familial environment stimulates curiosity in children and gives them encouragement to explore their interests with positive behaviors, attitudes, beliefs, and values (Campbell & Verna, 2007). Parental involvement in a child's educational activities, for example participation in open houses, parent teacher conferences, and social activities that include a parent-child discussion about education, are found to be influential to academic success and can increase a child's achievement as well (Bloom, 1985; Stewart, 2008). Conversely, children can also be persuaded to focus their talent development on areas that parents perceive as gender appropriate. Areas such as natural science and mathematics are particularly biased in favor of male children (Bhanot & Jovanovic, 2005; Geist & King, 2008; Jacobs & Bleeker, 2004). This pattern continues into adulthood, as parents are rarely found to encourage girls to pursue STEM careers (Lee & Sriraman, 2012; Sonnert, 2009).

Mentors are found as another positive influence in shaping a child's development. Studies have documented positive effects of mentoring on both disadvantaged and gifted children serving as teacher, expert, guide, advisor, friend, or role model (Clasen & Clasen, 1997; DuBois, Holloway, Valentine, & Cooper, 2002; Hamilton & Hamilton, 1992). Mentors are especially invaluable for economically disadvantaged students and minorities including females because these underprivileged groups are provided with academic resources and social support (Wright & Borland, 1992; Zorman, 1993). A mentor's good advice at the right time in a child's development could change the course of their life, and such examples are not rare (Muratori et al., 2006). On the other hand, not having a mentor to recognize one's talent and encourage a continued pursuit in mathematics was one reason given by women who once were gifted in STEM but decided to leave for the field of liberal arts (Lee & Sriraman, 2012).

Peers are found to have both a positively and negatively powerful influence in and out of school (Guimond, 1999). As relationships with peers are important in developing self-identity and psychological adjustment for general youth and the mathematically gifted, this relationship becomes more influential as a child gets older since adolescents tend to depend more upon peers for emotional support and spend more time with peers than with family members (Gumbiner, 2003; Marsh et al., 2006; Simpkins, Parke, Flyr, & Wild, 2006). However, results from Kao (2011) show a preference for seclusion and indifference to popularity for nine mathematically gifted females in Taiwan. Studies have shown that support and competition provided through peer groups can increase achievement and general enjoyment of learning because their work and advancement is recognized, accepted, and becomes popular (Kao, 2011; Peat et al., 2000; Ryan, 2001; Schapiro et al., 2009). Peers also provide a powerful influence longitudinally in students' academic careers as they make choices about attending college (Marsh et al., 2006; Ryan, 2001).

Provisions such as *competitions* and *training programs* serve students with domain-specific talents and/or interests in the area. Participation requirements to compete usually include school sponsorship, and winners often receive prizes or scholarships. Competitions can provide various advantages and disadvantages to participants academically, developmentally, and psychologically (Olszewski-Kubilius, 2010): Academically, competition and its preparation process can facilitate the development of ability, knowledge and skills, as well as tap into students' interest in the subject area. Competitions allow students to develop healthy attitudes toward competitive environments and enjoy opportunities to meet peers with similar interests. Being recognized for talents through competitions and contests was particularly significant when schools did not provide such recognition (Choi, 2010). However, students might develop anxiety or frustration with not winning. It could overwhelm individuals when scheduling preparation and participation on top of an already busy schedule.

Out-of-school programs, such as private or group tutoring, camps, or individualized supplementary programs can increase achievement and motivation for learners in need of remediation as well as those who seek acceleration (Pata et al., 2006). In Korea, group tutoring institutions called "Ha-Gwon" are regarded highly for academic success in advancing the studies of high achieving students (Kim, 2008; Kwok, 2004). For example, the Kumon-type method of individualized instruction, developed in Japan by Toru Kumon in 1954, is a popular option for out-of-school academic programs (McKenna et al., 2005). Assignments in such programs are designed to match any individual's learning pace and have been shown to help students retain mathematical knowledge (Bell, 2010; Benson & Baroody, 2002; McKenna et al., 2005).

Another category of influential factors that, according to Gagne's and Tannenbaum's talent development models, contribute to one's successful transformation of giftedness to high performance is **intrapersonal traits** – motivation, skills, perseverance, etc. (R. F. Subotnik, Olszewski-Kubilius, & Worrell, 2011). Similarly, an argument of Krutetskii (1976) on the necessity for one's success in mathematics overlaps with other researchers' categorizations of psychological conditions. After 12 years of studies with 201 gifted children, Krutetskii concluded that a student's success is derived from the combination of five characteristics (p. 74): (1) *an active, positive attitude toward the activity* and an interest in and an inclination to study it, which becomes passionate enthusiasm at a high level of development; (2) *character traits* that primarily include diligence, self-discipline, independence, clearness of purpose, persistence, as well as stable intellectual feelings (a feeling of satisfaction from intense mental work, joy in creation, and discovery); (3) a positive *mental state*; (4) a definite collection of *knowledge, skill, and habits* in the appropriate field; and (5) *ability,* that is, specific individual psychological characteristics.

Various types of *motivations* (e.g., intrinsic and extrinsic) are consistently at the center of high achievement and creative productivity (Covington, 2002; Nokelainen, Tirri, Campbell, & Walberg, 2007). Motivation-achievement models (Alexander & Schnick, 2008; Graham & Weiner, 1996) explain many psychological traits such as goal-orientation, self-perception, and task-orientation among gifted and non-gifted students and are a very important part of gifted education research. Whether intrinsic and extrinsic motivations yield different outcomes has been debated, however, studies (Covington, 2002; Kover & Worrell, 2010) report that high academic achievers utilize both motivational variables. Students are inspired through valuing what they learn (intrinsic) as well as proving themselves and being recognized for their accomplishments (extrinsic).

The role of *interest* is not only related to high achievement in academic domains but is also a channel to occupational choices (Su, Rounds, & Armstrong, 2009). However, in mathematics-intensive fields, interest plays a crucial role that creates disparity between women and men in studying and career choices in a particular area (Ceci & Williams, 2010; Lee & Sriraman, 2012; Su et al., 2009). *Passion,* as an extension of interests, is one way for a person to express a positive attitude that drives them to pursue exploration toward a specific domain of talents (Piirto, 1998). This aspect is often overlooked as an effect on talent development (Subotnik et al., 2011). Although many students are identified with general giftedness in their early ages without a sense of interest and passion in the talent domain, Tai, Liu, Maltese, and Fan (2006) found that it is not likely for these students to develop their talents as fully as those whose interests were accounted for.

Volition is a trait that involves an action toward implementation on top of a strong motivation toward the activity. In one's talent development, the volitional process functions to direct and control the individual's behavior and emotion to maximize goal attainment when the goal is not easy to attain (Corno, 1993). From the motivation element, volition requires one's commitment and action toward the area in which motivation is presented.

Many studies have investigated talent development of gifted individuals and how environmental and psychological conditions of this group affect their journey to high accomplishments. Among various groups of mathematically talented individuals, Rena F. Subotnik, Miserandino, and Olszewski-Kubilius (1996) assert that winners of International Mathematical Olympiad (IMO) are "a very selective group, yet their achievement stands as a benchmark for all gifted students" (p. 570). The high level of talent in IMOs is hardly coincidental, as participating countries send up to six high school students to compete in a unique system of competitions and training programs through which the final six students are selected. Typically, individuals in this group had rigorous goals in learning mathematics at early ages, which is a major factor in their talent development.

Korean teams have been in the IMO since first competing in 1988, bringing home 125 medals (46 gold, 58 silver, and 25 bronze) with 140 total participants as of 2010. Historically, only six of the 140 Korean Mathematical Olympians were female. In recent years, the Korean teams performed particularly well and were within the top 5, out of the participating teams, which amounted to over 90 countries. Studies focusing on IMO winners are limited, but include a study by S. H. Cho and Lee (2002) on perspectives of Olympians' parents and a study by S. Cho (2000) highlighting current and future directions to educate mathematically gifted students. Considering the interests of rearing future STEM leaders, it is beneficial to gain an in-depth understanding of how highly talented Olympians from Korea successfully develop their talent. Through interviews with five IMO winners from Korea, this study will examine (a) various experiences from out-of-school environments and intrapersonal conditions of the former Olympians and (b) how these factors influence academic development and achievement.

III. RESEARCH METHODLOGY

Data for this study was part of a larger study examining various influences on IMO winners' psychological conditions and academic development. Data collection was through in-depth interviews with five Korean Olympians and three of their parents focusing on influential environmental factors and psychological characteristics of the Olympians. The interviews examined different aspects of each individual's life experiences that impacted the student's academic achievement and the development of talent and interest in mathematics.

To explain a dynamic development from gifts to domain-specific talents in five Mathematical Olympians from Korea, Gagne's Differentiated Model of Giftedness and Talent (DMGT) is used as the framework for this study (2004, 2005, 2010). DMGT differentiates one's giftedness as a natural ability (aptitude) in at least one domain within the top 10% of an age group and talent as "the outstanding mastery of systematically developed ability (competencies – knowledge and skills) in a domain" that is also within top 10% of age peers active in the field (p. 82). During the systematic developmental process, various influences are accounted for when considering the accomplishments of a talented individual. DMGT constitutes five components – gifts, talents, talent development process, and two catalysts that are intrapersonal and environmental. The two catalysts are viewed as significant influential factors on one's talent developmental process. Other models of talent development generally acknowledge that the two catalysts – environment and psychological conditions - are influential for a child's talent development (Feldhusen, 1994; Piirto, 1999; Tannenbaum, 1983, 2003b). This study focuses on DMGT's two catalysts to examine how former Olympians' academic (particularly mathematical) talent development was influenced through Olympians' and their parents' retrospective lenses.

1. PARTICIPATES

To recruit participants for this study, names of all Korean IMO participants from the years 1997-2007 (total 54 participants) were taken from the IMO website (http://www.imo-official.org) and were searched through an internet search engine to first attempt to locate these individuals. Through this search, websites or email addresses were gathered for six IMO winners. These participants were contacted to inform them of the purpose of the study and request their participation, and three responded positively. Two other Olympians were introduced through email communication with the first three participants and also agreed to participate. Thus, through snowball sampling (Gay & Airasian, 2003), five participants were included in the study (Kim, Lee, Cho, Han, and Lim [1]), three females and two males.

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[1] Names are pseudonyms.

Through interviews, three of the five Olympians provided their parents' contact information to ask for their participation. All parents of the three Olympians' were willing to confirm Olympians' statements and provide anecdotal evidence.

Because of the centralized structure of Korean schooling, all Olympians received similar public education through middle school. From high school, educational experiences for these Olympians differed, because Korean students have several options for specialized high schools (Choi & Hong, 2009). All five were eligible to enter specialized science high schools because of high performance in mathematics competitions, and four chose to enter specialized science schools while one chose to remain in a regular high school.

2. DATA COLLECTION

Individual interviews were conducted to gather data for the study. Participating Olympians and parents took part in three one-hour interviews, which were recorded and transcribed verbatim immediately. The interview questions have an open-ended, partially structured format, with some questions taken from previous studies (Karp, 2003; Muratori et al., 2006). For example, Muratori and colleagues reported that mentors are an influence to former Olympians, from which this study adopted the related questions about the role of mentor relationships in talent development. Psychological characteristics including positive attitudes toward mathematics, character traits, positive mental state toward its implementations, and knowledge, skills and habits were the focus of interview questions. Through the partially structured format, interviewees could elaborate on additional, relevant information on the questions asked and the interviewer could expand and modify the prepared questionnaire based on responses received. As interviewees provided new information and unidentified areas of influence, additional questions were developed for following interview sessions to help explore the new information. Email communication was used after the interviews to provide further clarification as needed.

3. METHODS OF ANALYZING DATA

When research questions were written, they were to investigate each category of influential factors discussed earlier. Since the current study was framed around two catalysts of DMGT of Gagne (2005a, 2005b, 2010), the subcategories of two catalysts were determined to construct interview questions. Questions from previous studies (Karp, 2003; Muratori et al., 2006) were adopted and modified to meet the needs of the current study – environmental catalyst (persons and provisions) and intrapersonal catalyst focusing on motivation and volition in this study (a positive attitude toward mathemaitcs; characteristic traits; a favorable mental condition to its implementation; a definite fund of knowledge, skill, and habits as in Krutetskii, 1976) that "actively moderate the talent development process" (Gagne, 2010). Among many components of intrapersonal catalysts, motivation and volition are the two crucial elements that explain decision-making and implementation of the decision. The interviewee's statements were compared with regard to each sub-category. In addition to already known influential factors, interview transcripts of eight interviewees were analyzed through constant comparison to discover additional evidence.

Transcripts were analyzed as soon as each interview session was completed, first on a question-by-question basis to categorize responses into two catalysts – environmental and intrapersonal. Once the environmental catalyst was determined, interview statements were subcategorized, for a second round of coding, by each catalyst including *persons* (family members, mentors and peers, etc.) and *provisions* (mathematics competitions, training programs, afterschool educational programs, etc.). For the statements categorized as intrapersonal catalyst, the second round coding looked into *motivation* (interest, passion, positive attitude toward activities, study habits, and intrinsic motivation) and *volition* (positive attitude toward implementations that involve commitment and action). After follow-up interviews, data from these interviews were compared to the data from previous interviews to find similarities and differences. Once all three sessions for each participant were completed, a microanalysis approach was undertaken with a sentence-by-sentence analysis of selected key words.

Three independent coders analyzed transcripts, first, question by question, and then sentence by sentence until all transcribed sentences were identified with at least one category and no further sub-categories of two catalysts could be added. Coders were instructed to code each sentence on at least two different occasions before finalizing the code. When a sentence was unable to be categorized as a previously identified factor, it was set asides for further analysis and later reviewed by the first author to identify additional sub-categories. Through this process, additional factors were added. After additional factors were identified, the other two coders worked on coding with the additional factors.

4. VALIDITY AND RELIABILITY

The credibility of a study's results and interpretations depend on "careful attention to establishing trustworthiness" (Glesne, 1999) and on a sufficient amount of time spent in the field and making careful observations (Lincoln & Guba, 1985). Measures were taken to ensure both of these criteria for validity. The researcher met with each interviewee for three one-hour interviews, which gave sufficient time for interviewees to become comfortable with the interviewer and share their experiences, and multiple interviews allowed for the researcher to ask questions and explore interviewees' responses from all angles. Further correspondence through email helped to further clarify the results. Interviews of the parents also helped authenticate and triangulate the results, which made findings more trustworthy. Reliability of analysis can be shown with agreement rates of over 92% from three independent coders. Transcripts were analyzed multiple times on separate occasions by these three coders. Bias of analysts was reduced through repeated analysis on separate occasions by multiple reviewers, which should make findings more reliable.

IV. RESULTS AND DISCUSIONS

In this section we will report on the sources of influence for these IMO winners and describe some specific instances they recalled to be of particular significance to their development in mathematics. The interviewee comments we share represent the common themes we saw through analysis of the data.

1. THE ENVIRONMENTAL CATALYST

Analyses of the interviews revealed five major sources of influence for the five Korean IMO winners' talent development for the environmental catalyst category. The findings in the 'persons' subcategory – family members, mentors and peers -- were consistent with previous studies. For the 'provision' subcategory, participation in mathematics camps and training programs were influential sources that have been discussed in previous research. One additional influential factor was discovered through this study – private educational practices such as mathematics workbooks and Ha-Gwon, private group tutoring institutions – that were seldom mentioned previously.

1) Family Members.

All Olympians revealed that parents and family members were influential directly and indirectly to their success starting from an early age. Parents and other family members provided the help necessary to further develop their children's talents, including a variety of learning activities, and inspiring their children to believe in one's potential and interests. Some participants appreciated these endeavors and paid tribute to their parents for their interests and success in mathematics. The types of positive support provided by family members, such as exposure to various reading and other educational resources at home, align with suggestions of positive support given in previous studies (Campbell & Verna, 2007; Cox et al., 1985).

Three Olympians mentioned that their parents arranged a weekly mathematics workbook delivered to their home. The motivation parents showed to engage their children in mathematics workbooks were due to their children's visible interest in mathematics. Kim's mother started making up simple mathematics calculation problems to occupy him while she was working. He completed them quickly and asked for more problems. Kim's mother could not keep up with his speed and decided to order weekly workbooks for him. Han and Lim also found their mothers contributed to developing their interest in mathematics through encouraging and providing work at home. However, the way that their parents encouraged them did not stop at providing mathematics work for their kids. Lim commented on her mother's influence:

> My mother never pushed me to work on [mathematics workbook], rather, she tried to work with me and incited me to have interested in solving problems. She taught and explained whenever I asked questions. This helped me gain confidence. My mother probably did not intend to raise me as mathematician, but it worked out this way.

Many of Kim's family members contributed to the development of his interest in mathematics. Kim's grandfather inspired the love of numbers and mathematics at the age of two by reading numbers to him whenever they saw numbers. Before Kim started speaking, he recognized numbers and was able to read them. His father, who also had an interest in mathematics, taught Kim simple non-routine calculations, such as how to find a square root manually, starting at the age of five.

Cho's motivation for learning stemmed from his mother's love for reading. His mother explained how her passion for reading inspired her children to acquire a habit of reading and learning.

> Rather than watching TV or videos, I thought reading books were beneficial to my children. Whenever I had spare time, I sat down with a book and started reading it. My children, a daughter and a son, played together and time to time checked on me what I was doing. When they got tired of playing, they came and sat next to me with their books. This was how they developed the routine and habit of reading books.

Searching for extra help for Lee's talent in mathematics, Lee's mother took her to a local Ha-Gwon while Lee was an elementary school student. Lee's talent in mathematics was recognized among other mathematically bright peers in the Ha-Gwon. This became a turning point for Lee to pursue mathematics competitions. Also, his father quizzed Lee in mental calculations starting at a young age, where Lee performed better than older siblings, and she developed the love for and confidence in mathematics and determination to work hard in her studies as a result of this parental interest and support.

2) Mentors and Peers

Mentors are frequently mentioned in studies of influential factors on talent development. Three of the five participants made notes in the interviews that they had at least one mentor who influenced their studies in mathematics. The mentors played an important role at different times in these students' academic lives, ranging from elementary school to college and beyond. The Olympians' mentors played important roles in the Olympians lives, which is consistent with statements mentioned as significant in previous research (Clasen & Clasen, 1997; Lee & Sriraman, 2012). Mentors such as teachers, advisors, parents, and peers provided important guidance directly through conversation or indirectly by being role models for the participants in this study. These mentors played an important role in steering the choices of the Olympians toward further study in mathematics at particular junctures in their educational experiences.

Lim had teachers, parents, and peers who counseled her throughout her years in school. The first mentor Lim had was an elementary school teacher in charge of the after-school mathematics program. Lim said, "He did not teach a great deal of mathematics to me, but he sent me to mathematics competitions at the right time. … He played an essential role to provide me such chances." Valuable mentors, such as Lim's college advisor, continued advocacy and support through college, as she took steps towards becoming a mathematician. Her college advisor was a professor who trained Mathematical Olympiad finalists and led the Olympians to the IMOs for years. The professor not only played a teacher role but also offered advice when Lim was making important decisions for her future studies and career.

Mentors also created opportunities and provided guidance as Olympians took steps toward careers in mathematics, but one particular mentor was prominent in an Olympian's decision-making process as Cho chose to step away from mathematics. Cho's most invaluable mentor was a college advisor who guided her throughout undergraduate study and multiple thesis papers. When deciding to change her field of study after graduating college, the advisor expressed the most disappointment and told her not to hesitate if she decided to return to mathematics.

> At the time, I told him of my intention to change my major to [something else]. Dr. Adams showed the most disappointment while other professors expressed simple worries and understandings in my determination. He even recommended taking some time off from mathematics before making a solid decision in changing my field of study. Later, at commencement, Dr. Adams told me to contact him if I wanted to come back to mathematics. Personally, I felt he took good care of me and he affected me the most academically and professionally.

Mentors affected the choices along each Olympian's academic path, and sometimes the sources of influence were unaware of their impact. A role model Lee mentioned was a senior student who was four years ahead and had attended the same middle school, high school, college, and graduate school as she did. When the alum, which was a former Olympian, was featured in Lee's middle school newsletter for accomplishing a perfect score at the IMO, it was the first time Lee learned about him. This role model of Lee's may not have known the impact his performance had on Lee at first, but his example served as a guide for Lee who worked to follow the former Olympian's steps. Later, they met and Lee received guidance from him personally about "how to study for a career" in mathematics. Lee applied to the same Ivy League graduate school "without hesitation" and was attending this school at the time of interviews.

Although Kim did not acknowledge an adult mentor and actually expressed a lack of a mentor during the life journey, Kim did mention the influence of the same former Olympian as Lee.

> I don't think I have anyone to call a mentor, but I observed [a former Olympian that Lee mentioned]. From how many hours to study a day to making decisions in coming to [the U.S. university Kim attends], I took notes of his examples and followed this advice without hesitation.

3) Mathematics Competitions

Although only two of the Olympians mentioned competitions as a direct influence on their development, four of the five made a reference to experiences at competitions when they were interviewed. The experiences of the Olympians reveal many of the advantages such as facilitating the development of problem solving skills in the process of preparation, developing a healthy attitude toward competition, meeting like-minded peers, and providing a way for these individuals to be recognized for their efforts (Olszewski-Kubilius, 2010). None of the negative aspects of competition, such as anxiety or overwhelming schedules, were brought up by any of the Olympians of this study.

Medals earned at competitions spurred three Olympians to confirm their interest and ability in mathematics. For Lim, winning the IMO reaffirmed her passion to pursue mathematics as a career and strengthened her resolve to continue despite obstacles she had experienced. Cho reflected on her experience at a mathematics competition sponsored by a workbook company, where she earned a bronze medal.

> [Winning the bronze medal] led me to like mathematics more and probably the very reason I began to seriously think about mathematics... If not [for the] mathematics competitions, I would not have started thinking about studying mathematics let alone major in it.

Han was interested in both mathematics and science and had participated in both competitions. Until middle school, he leaned toward science more than mathematics, however when realizing that his competition achievement in mathematics was higher than in science competitions, Han decided to focus on studying mathematics rather than science.

Cho used the IMO as a stepping-stone to enter prestigious schools and saw her performance as an important advantage for acceptance into undergrad and graduate schools. Cho also mentioned other important personal and psychological benefits of competitions and awards. Receiving awards from competitions is more than a simple reward. It was a payoff of personal physical and emotional efforts and investment over many years that one puts in.

> First of all, self-confidence. Even though I cared about my GPA and spent much of my free time preparing for mathematical competitions, I studied very hard for several years. After putting in so many years of hard work, it was a huge difference between receiving the award at the end and not. Just because others said it was good to get the award did not mean that it was necessarily worth all that hard work. After a certain point, you would see good results from the effort you put in.

While preparing for competitions, high achievers in national competitions go through mandatory training programs or mathematics camps, where they found like-minded peers. This positive effect of competitions will be introduced more in the next section.

4) Training programs (mathematics camps)

To become one of the six Olympians for the year's IMO, students in Korea have to go through a series of regional, national competitions and invitation-based training programs

(See Choi, 2010, for a detailed sequence). One of such is a summer or winter training camp, to which a small number of selected high achievers from national competitions are invited. It was mandatory for the pool of IMO winners to join the camps and receive training. In turn, all of the interviewees joined in the camps at least once before being selected to advance to the IMO. All of the interviewees expressed that they enjoyed participating in these programs. These camps provided a connection with like-minded peers, advanced mathematical training, and exposure to prominent mathematicians, all which helped to develop their interest and passion for mathematics. These Olympians were already high achievers in their regions of residence and contended with it, however, at the camps they realized there were other people who were equally high achieving or better than themselves. Some declared that without the camps they would not have worked as hard or made the same level of achievements.

Female Olympians recalled how excited they were to meet other female peers who shared the same passion in mathematics. “Among the 40 to 50 participants, there were always less than 10 girls. Soon, four of the girls who were always there for every camp became very close,” Lim said. Cho also addressed her excitement to meet other female students saying that meeting other female students motivated her more than learning advanced mathematics, which she also enjoyed. Cho explained “I strived even harder to go better at the national mathematical competition to get into the camp to be connected with these girls.”

Former Olympians and professors who spoke or gave lectures at the camps made lasting impressions on Han, Kim, and Lee. Han, who was the only interviewee that did not attend a specialized high school, described the camp as an overwhelming experience for him. Han was a bit hesitant to spend time in the training camps because “the schedule looked dreadful – studying all day long for days” and school teachers did not mind Han’s decision not to go for it. However, Professors’ lectures changed his perspective of mathematics, helping him think of mathematics not as a hobby but as a goal to pursue. Han said, “Overall, participation in this [first] camp encouraged me tremendously… After this experience, I was more excited in participating in competitions, wanted to achieve better at competitions to be invited to the next camp, and readjusted my perception about mathematics.”

The teaching assistants (TAs) at the camps were another motivating factor for Lee and Han. Usually, TAs were college students who were once Olympians or high achievers from national mathematical competitions. They not only helped participants learn mathematics but also shared their personal experiences involving mathematics competitions including the IMO. One TA willingly shared his collection of competition preparation books with one Olympian when she was struggling to find more resources. In fact, Han later served as a TA eight times because of his appreciation for what these camps offered.

5) Private education: Workbook and Ha-Gwon

All five Olympians expressed the importance of mathematics workbook practices, Ha-Gwon, or both in their academic pursuits. Workbooks, mentioned frequently by former Olympians and their parents, are usually delivered weekly to students' houses based on individual academic standing and progress. A designated instructor delivered mathematics workbooks and checked a child's progress, however, they did not visit to teach mathematics. Olympians received workbooks and were able to quickly advance to higher-level mathematics than their age groups usually learn. Ha-Gwon is a common name for unique Korean private education institutions, where groups of students study virtually all academic subjects either to advance or to catch up with school curriculum. The intensive training from these outlets prepared interested students for mathematics competitions in a way that school would not.

Lim and Han started using the workbooks to advance their mathematical skills at a young age and spent time at a Ha-Gwon during their middle school years, which proved valuable for both. A Ha-Gwon that Lim attended was to enhance school subjects as well as to prepare for competitions. Attending every day during three years of his middle school, Han emphasized how influential the Ha-Gwon was to his academic success. "I enjoyed the environment that allowed me to study liberally [on their own pace]… Personally, I liked the way I and my peers studied independently and received support from teachers whenever we needed help from them."

The flexible style of the mathematics workbooks helped Cho and Kim set their own pace for learning and contributed substantially toward their success. Both started using the workbooks at a young age, and the flexibility of the workbooks enabled them to learn based on their ability instead of their age. In fact, Kim finished high school level mathematics in the fourth grade. Kim explained, "Since I learned faster than other students and wanted to work more, the instructor provided twice more materials than what was supposed to be and let me advance to the next level as soon as possible."

Lee's mother first discovered her child's mathematical talent and sought help from a local Ha-Gwon. Her score on the entrance test was high enough to receive special intensive training in mathematics. Two to three days per week Lee went to the Ha-Gwon to learn advanced mathematical topics. This experience helped her develop confidence and fondness toward mathematics.

2. INTRAPERSONAL CATALYST

1) Motivation

All five Olympians express strong motivation to do mathematics from early on in their lives. Lim's positive attitude toward mathematics was so strong that she could overcome her anxiety toward testing situations. Lim "suffer[ed] severely from anxiety problems. Especially, if a test is timed, I get more anxious." She thought, "Although there is no cure for anxiety, there must be a way to overcome it. I tried to prepare as perfect as possible… If you cannot find your own way to overcome it, you may face failure." It was clear that Lim's motivation to advance in mathematics enabled her to overcome anxiety issues.

For Cho, the interest to learn more was not limited to mathematics. Cho's mother took her children to bookstores regularly when they were young, Cho's selection of books included psychology, philosophy, social science as well as various sciences. This interest in learning continued when she entered college where she took classes in physics, biology, computer science, architecture, aesthetics, and economics on the top of Cho's major – mathematics.

This does not mean that Cho liked mathematics any less. Early on, Cho demonstrated the fondness in learning mathematics when she was staying home for a few months to recover from an accident. While staying at home, she read all the available books and completed mathematics workbooks that were designed for older students.

> My mother brought story books for me to read until there were no more and suggested to work on middle school mathematics workbooks. Since I was bored and liked mathematics, it was fun to learn by reading mathematical concepts and to solve different problems, applying what I had just read. I finished two years' worth of middle school mathematics that winter.

In addition to the books her mother provided that stimulated Cho's intellectual and academic interest, Cho's interest for learning mathematics and quick and focused learning and indefatigable study habits made it possible to complete higher level mathematics in a relatively short period of time.

Han's interest in mathematics, intertwined with awards from high achievement at mathematics competitions, developed into a passion. From third grade, Han found interest in mathematics, which later turned into passionate enthusiasm. He was awarded at a mathematics competition for the first time when he was third grade and from then on, "I became interested in mathematics because I felt I was good at it… By the end of elementary school, I received more prizes and came to like mathematics more, and consequently, found more interest in mathematics than any other subject." Han also explored another field as his test score in science was also good. However, Han turned back to mathematics “maybe because [he] got more awards from mathematics competitions or [he] felt more recognized when competing for mathematics.” When asked to elaborate more on whether “being good at” comes before “liking” mathematics, Han said “I liked what I was good at in the beginning but, in the end, I was good at what I liked.” Han’s passion toward mathematics was supported and strengthened by recognition and awards.

Kim’s mother witnessed her son’s special interest in numbers when he was a toddler. His mother recalled that Kim’s verbal development was slower than Kim’s recognition of numbers. One critical incident that lead to his mother’s instinct tremendously influencing the future development of Kim’s talent was that the mother identified her child’s interest and giftedness in mathematics. Before Kim reached a school age, his mother took him to her workplace where she gave Kim addition and subtraction problems to keep him quiet. Kim completed them quicker than she expected and asked for more. When Kim’s mother realized that she could not keep up with her son’s speed, she decided to arrange weekly mathematics workbooks for Kim. Kim’s mother explained what came after.

> Before entering elementary school, a visiting weekly mathematics workbook instructor tested DP and began to take an interest in him. I did not want to push my little boy to study at such a young age, however, DP showed strong desires to learn mathematics and completed week-long assignments in a day. The instructor provided twice the amount of material as DP wished, but it did not satisfy him. By the end of fourth grade, DP completed material at the high school level.

Manifestation of Kim’s passion for mathematics did not end at reaching the highest level mathematics workbook available. Kim’s mother mentioned that Kim was also eager to beat his own record he set previously. “Whenever he got a new assignment, Kim asked me to time his work because he enjoyed beating his own previous high record.”

As Kim got older, his passion for mathematics became stronger and solid. Kim was already determined to pursue mathematics for his career since “the third year of middle school, I never thought about studying or majoring any other area than mathematics. Other people suggested medicine and my father suggested engineering, but I told them that I would do mathematics until I lose interest in it.”

Lee was more attracted to the nature of learning mathematics. When asked which subjects she liked when in school, Lee stated “unlike other subjects that require a lot of memorization, for mathematics, I did not have to do that. It must be a reason that I like mathematics.” Recognition and awards from high achievement was also another influence that helped Lee realize her interest and fondness in mathematics. When Lee was tested for mathematics in sixth grade, she scored the highest without any preparation. Lee said “I felt more confident when others recognized me as being mathematically smart” and my interest toward mathematics became stronger when “others recognized and appreciated my talent.” However, Lee concluded that she found herself liking mathematics because “to [her], it was fun and interesting to solve challenging mathematics problems.”

2) Volition

The second focus of intrapersonal catalyst in this study, volition, is referred to as post-decisional. In terms of action and time of the action, it happens after their decision for implementation.

Lim’s determination to pursue further study in mathematics was apparent when she was suggested to another field of study. Lim’s father holding a related background, advised her to pursue a field that was more financially secure, such as medicine. However, Lim remained firm about a profession in mathematics. Lim recalled this conflict with her father, stating, “I knew it [listening to my father’s advice] would make my life easier, however, I was very stubborn and not really affected by others’ opinions even though it was my father’s.” Earlier when in middle school, she had another goal that she was after. Lim was determined to enter a specialized science high school because she was bored with slow-paced mathematics instruction, describing herself as a teenager “full of complaints”. However, to enter, she had to maintain a near-perfect GPA or be accomplished at national level mathematics competitions. Since her grade point was not as high as she wanted, her only chance was to successfully compete.

> It was really stressful because my school did not provide me access to regional competition until the third year of middle school no matter how well I did at the in-school competition during my first or second year.

Cho experienced a similar situation while in middle school and was determined to enter a specialized high school.

> I strongly disliked my middle school because of the environment, peers, even the teachers who forced me to keep up with slow-paced lessons. A few times, I attempted to quit and leave school. However, to enter the specialized high school that I wanted to, I had to have a middle school diplomat and to have really good grades. For those reasons, I was determined to earn good grades and endure until graduation.

Cho was able to earn the highest GPA among the year’s graduates and was able to enter the science high school she desired. For the other Olympians, they did not report any struggle in securing entrance to specialized high schools, however, they paid their utmost efforts to other goals.

Kim highlighted his efforts to prepare for mathematical competitions and Olympiads explaining that he never gave up on mathematics problems that he could not check for correct answers. Because Kim had incomplete resources and materials with some missing pages and answers, for problems that he was not sure about, Kim never gave up and went back to solve each of them until he had them worked out.

For female Olympians, it was particularly difficult for them to find a peer to share their passion for mathematics with in school or in their neighborhood. They found each other while attending mathematics training camps for high achievers at national mathematics competitions and attending those camps became their goal to pursue. Because only 30-50 students are invited to each training camp and the proportion of female attendees is always small, female contestants rarely meet. All interviewed female Olympians in the study recalled how much they enjoyed meeting other female peers at the camps and they were determined to be invited to the training camps every year and going to the camp became a preceding goal to winning awards or recognition. Cho recalled that "the first time I participated in the camp was during the second year of my middle school. … I studies harder in order to be invited to those camps." It was apparent that these female Olympians possess a positive mental state for an implementation (camp).

V. DISCUSSIONS AND CONCLUSION

Gagne (2010), in his DMGT, explained how a raw gift (natural ability) transformed into a talent (systematically developed skills). In this developmental process, two major catalysts – intrapersonal and environmental – impact individuals (see figure 1, in Gagne, 2010). In this study, two elements, persons and provisions, of the environmental catalyst were investigated in how they influenced former Olympians' development of mathematical talents from natural ability from early ages. For the intrapersonal catalyst, motivation and volition are found to be crucial elements for a gifted child who is training to become a talented achiever. Private education was a new component to the provisions under the environment catalyst that had rarely been identified from previous studies. Ha-Gwon, a private tutoring, is particularly popular in some Asian cultures that provide extra learning opportunities for students who seek advancement in academic subject areas (Kim, 2008).

Among aspects of the environmental catalyst, several findings are noteworthy. Many parents provided mathematics instructions for their children. They were as simple as to provide simple calculation problems to keep their young ones quiet or to answer mathematics questions brought to parents. Some parents offered quite complex problems such as finding square root values without suing a calculator or taught accelerated content when the parents found it is useful to do so. The common theme here is that parents carefully observed their children on what they were interested and able to advance in. Knowing that offering calculation problems would keep a boy quiet for some time and later finding that “simple” problems would not last long, lead to the arrangement of mathematics workbooks, which stemmed from a mother’s scrutiny on her child. In fact, parents mentioned providing help on mathematics learning shows not only parents’ capability to do so but also parents response to children’s potential and requests, whether it was in the form of teaching how to solve mathematics problems or to arrange additional resources in order to meet their needs and interests.

One cannot mistake that this form of support requires parents to have advanced degrees in a certain area, as did some of the parents in this study. As one parent recalled that her child had interests in various areas other than mathematics, this mother took her child to a local bookstore regularly and let the child to select books to read. What is more important is that the mother spent time with her children and took advantage of those times to observe and understand the child and offer resources based on each child’s needs.

Another interesting point is the dynamic play between parental belief and former Olympians’ volition. Family influence on career choice of gifted students, especially mathematically gifted girls, of this study is contrary to the findings of Lee and Sriraman (2012), who described the situation of two mathematically gifted Korean female students who ultimately chose to pursue non-mathematics careers because of family and societal experiences early in their lives that gave negative perceptions towards females as mathematicians. In terms of parents’ perception on mathematics as a career, parents in the current study were not too different from Lee and Sriraman’s study. Some parents in this study perceived mathematics career paths as less than ideal for their children, especially for girls. What was different was that parents of former Olympians’ ultimately recognized their child’s mathematical talents, strong motivation and volition, and commitment to pursue mathematics and respected the children’s decision. A dynamic interaction between parent’s beliefs on their child’s talent reinforced by the child’s volition and commitment resulted in their decision to purse mathematics as a profession.

All of the Olympians who mentioned peers and mentors as having an impact on their mathematical success found them to be valuable and influential in providing opportunities and giving social guidance throughout the students’ academic pursuits. This parallels the findings of previous research (Clasen & Clasen, 1997; DuBois et al., 2002). Although many different people aided these Olympians in finding success in their talents, one of the most influential out-of-school influences these Olympians had access to was their participation in mathematics camps. Through these camps, the Olympians met other high-achieving and like-minded peers who were invited to partake in the camp because of their exceptional performance in other national mathematics competitions. These camps allowed the high-achieving students to meet peers with similar talents, receive advanced mathematical training, and meet prominent mathematicians who helped instill a passion for the subject.

The peer effect was particularly significant for female Olympians. The three female Olympians in this study manifested that their favorite aspect of training camps was to meet other female students who were good at mathematics. Coming from public schools where it was difficult to find same-gendered peers with similar intellectual interests, going to the training camps to spend time with other mathematically gifted girls became one of the primary goals of these female Olympians. They immediately developed a strong bond and most of them have been taking similar educational and professional paths until now.

Through an awareness of the influences on the mathematical development of these Olympians, parents, educators and school administrators can become more aware of the supports that should be considered when aiding their children and students. With these supports in line, the five Olympians in this study were able to find high levels of academic success in an optimal environment for each individual, both in and outside of school. This study assumed that competition experiences positively influenced mathematically gifted students. As one Olympian remarked during an interview, there are many other gifted individuals studying mathematics at prestigious colleges around the world whom never competed at Olympiads. This may not be applied to all mathematically gifted individuals and it is noted that some mathematically gifted students may suffer anxiety in highly competitive environments. The same principal should be applied to other environmental factors. In other words, it does not mean that all of these factors need to be in place in order for a child to succeed in mathematics. Parents and teachers should take a caution when they consider sending their mathematically gifted children to competitions. However, it is helpful for parents, specifically, to be aware of the out-of-school factors that they have more control over, as opposed to the in-school factors that educators and administrators would need to be more aware of (Choi, 2013).

Schools should also play a major role by educating parents on traits and development of mathematically gifted children. As identified, there are various resources that high achieving students could seek outside of schools. Gifted programs could provide advanced curriculum, like-minded peers, mentors and other additional resources. It should be noted that not all families are able to afford additional private educational practices. It would be beneficial for schools to provide systemic activities that are suitable for individual students and the development of their interests and talents, as well as environments conducive to the discovery of one's potential.

In the history of Korean IMO competitions there have been few female contestants. This pattern is consistent throughout other countries as well. For this study we were able to recruit three female Olympians, and were able to learn about the influences on successful female mathematics students. Although this study did not solely focus on female Olympians, it creates a good starting point in understanding the development and achievement of females in STEM professions, especially in mathematics, in hopes of encouraging a higher rate of participation in future IMO competitions.

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