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Influence of Family Processes, Motivation, and Beliefs About Intelligence on Creative Problem Solving of Scientifically Talented Individuals

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Predictive relationships among perceived family processes, intrinsic and extrinsic motivation, incremental beliefs about intelligence, confidence in intelligence, and creative problem-solving practices in mathematics and science were examined. Participants were 733 scientifically talented Korean students in fourth through twelfth grades as well as 71 individuals in fifth grade, tenth grade, and former Korean Science Olympians. Across all students, perceived positive family processes directly predicted creative problem-solving practices in mathematics and science and were indirectly predicted through enhancing confidence in intelligence and intrinsic motivation, which, in turn, predicted students' creative problem solving in mathematics and science. Confidence in intelligence was the best predictor of creative problem solving for scientifically talented fifth- and tenth-grade students but not for Olympians. Alternative interpretations, the importance of confidence in intelligence for creative problem solving in mathematics and science, and educational implications are discussed.

Keywords: belief about intelligence, confidence in intelligence, creative problem solving, family processes, intrinsic motivation

Olympians and scientifically talented students are likely to become creative and productive scientists who contribute to the development of science fields, but not all gifted students become creatively productive adults (Hennessey, 2004). Scientifically talented students may need certain psychological characteristics to be creative scientists. However, few studies exist on the predictive relationship between related psychological factors and the development of creative productivity of scientifically talented individuals.

Recent studies accede that creativity is domain specific (Baer, 1999; Han & Marvin, 2002; Hennessey & Amabile, 1988; Weisberg, 1989). Yet, very few studies deal with creativity in mathematics and science, where creativity is interchangeable with creative problem solving, because creativity is employed and exhibited during problem solving. Creativity is applied better when the problems are open-ended and ill-defined (Kaufman & Sternberg, 2007; Sriraman, 2006) and best exhibited when the solutions are novel and useful (Runscio & Amabile, 1999). This interchangeability is also suggested by Weisberg (1989, 1999), who asserted that creativity in problem solving involves problem finding to the execution of the plan.

Accordingly, creativity is exhibited by novel and appropriate solutions for problems in a specific domain. However, creativity measured by psychometric instruments is limited to divergent thinking (e.g. Guilford, 1971; Torrance, 1974; Wallach & Kogan, 1965) or personality types (Selby, Shaw, & Hovtz, 2005; Williams, 1980). More valid criteria for the measurement of creativity in mathematics and science should include the occurrence of novel and appropriate solutions.

The creativity measure used in this study is the Creative Problem Solving Practices in Mathematics and Science (CPSMS) scale, a self-reported measure of how often a person practices solving problems with novel and appropriate solutions in mathematics and science. CPSMS is repeatedly found to be most positively related to and the best predictor of actual creative solutions in mathematics and science (Cho, Ahn, & Han, 2004; Cho & Han, 2004; Cho, Han, & Ahn, 2005).

To produce novel and appropriate solutions, the dynamic interaction among cognitive (divergent thinking and acting, general knowledge and skills, and knowledge and skills in a specific domain), affective (focusing and task

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commitment, motivation and motives, and openness and tolerance for ambiguity), and environmental components is necessary (Kaufman & Sternberg, 2007; Lubart, 1999). Just one or two components do not guarantee a person's creative productivity. An optimum combination of multiple psychological components is needed for a person to produce creative solutions, but few studies have determined the predictive relationships among these variables, especially from a developmental perspective.

The first purpose of this study is to ascertain the psychological attributes related to creative problem solving (CPS) of scientifically talented Korean students. It is hypothesized that scientifically talented Korean students will report positive family processes, intrinsic motivation, incremental beliefs about intelligence (BAI), confidence in intelligence, and high CPSMS, because these students have been identified with high creative problem solving abilities in mathematics and science. In addition, all students will report high incremental BAI because, in Confucian cultures, it is believed that success is more effort than inherent ability (Sorensen, 1994; Watkins & Biggs, 1996). The function of extrinsic motivation is controversial for CPS (Hennessey & Amabile, 1988). In this study, it is hypothesized that extrinsic motivation will be very high because the educational system and Confucian culture of Korea influence the association between high academic achievement and individual and family success (K. H. Kim, 2005b; Lee, 2005).

The second purpose of the study is to investigate, from a developmental perspective, the relative predictability of perceived positive family processes, personal beliefs about intelligence, and motivation on CPSMS with scientifically talented Korean students and former science Olympians. Korean students under the influence of a Confucian culture are clearly aware of their parents' aspirations for their academic achievement (Cho, 2007; K. S. Kim et al., 1994; Y. H. Kim, 1992), which affects their beliefs about intelligence and motivation. Therefore, it is hypothesized that perceived family processes will predict personal beliefs about intelligence and motivation, which, in turn, will predict students' CPSMS. As children grow up and positive family processes are gradually converted into personal beliefs and motivation, these personal characteristics will eventually better predict CPSMS. However, when children are young, the family process will predict CPSMS better. Confidence in intelligence is expected to predict CPSMS better than incremental BAI because there is little difference in beliefs about the incremental nature of the intelligence among Koreans.

The third purpose is to compare scientifically talented students and former Olympians in terms of psychological features related to CPSMS. Former Korean Olympians have already proven themselves as creative in the science, technology, engineering, and mathematics (STEM) workforce by winning international competitions that require high creativity in problem solving (Campbell & O'Connor-Petruso, 2008), whereas scientifically talented students have yet to prove their potential. It is hypothesized that the psychological variables of intrinsic motivation, incremental beliefs about intelligence, and confidence in intelligence, but not extrinsic motivation, will predict CPSMS of former Olympians and scientifically talented students to slightly different degrees. Moreover, positive family processes will predict CPSMS of scientifically talented students who are younger than the Olympians.

Recent studies suggest that young adolescents' personal beliefs about their abilities and motivations are influenced by their perceptions of the social and psychological environments (Eccles, Midgley, et al., 1993; Eccles, Wigfield, et al., 1993). CPS practices in mathematics and science of scientifically talented Koreans should be understood with the impact of a Confucian culture and the general and gifted educational systems of Korea in mind. Confucian culture emphasizes the importance of education, high expectation of student achievement, attribution of achievement from effort rather than from innate ability, and a serious attitude toward studying (Campbell & Wu, 1994; Park & Leung, 2003; Sorensen, 1994; Watkins & Biggs, 1996). The Korean family structure is characterized by a corporate family organization with a strong family head, a clear division of labor, filial piety, and influence on a child's education (Sorensen). Therefore, family processes are effectively implemented for children to achieve highly (Campbell & Wu; Cho & Yoon, 2005) and offer motivation for them to succeed for the sake of their family, if not for themselves (Sorensen).

Additionally, the Confucian emphasis on *joy of learning and practice* helps students develop confidence in their own skills and capability, thereby developing intrinsic motivation in learning, which gradually builds a firm base for CPS (Cho, 2007; Park & Leung, 2003). In contrast, the Confucian value of hierarchical order in which obedience is required discourages students to develop and think independently (K. H. Kim, 2005b).

The current evaluation system in Korean general education is averse to nurturing students' creativity, because Korean students need to perform better than other students in a unitary evaluation system without alternative choices (Bong, 2008). The introduction of a gifted education into the Korean education system in 1983 increased opportunities for gifted students to practice CPS with ill-defined and unstructured mathematics and science problems (Cho, 2000; Cho & Hwang, 2006; Choi & Hon, 2009; H. Kim, Cho, & Ahn, 2003; H. Kim, Cho, & Jeong, 2003).

Despite the influence of the Korean educational system, family is assumed to play a more salient role in the CPS practices of Korean students because of the unique Korean family structure (Bong, 2008; Sorensen, 1994), which is influenced by Confucian culture. Understanding the predictive relationships among variables related to CPS practices of scientifically talented students in mathematics and science and past Olympians is critical for finding more efficient ways to nurture CPS ability.

Researchers have addressed personal beliefs about ability or motivational aspects to understand individual differences in CPS. Intrinsic motivation is the most frequently cited predictor of creativity (Hennessey & Amabile, 1988) and directly related to taking risks in scientifically talented Asian students (Cho, Han, et al., 2005; Moneta & Siu, 2002).

Another influential factor in children's creativity and achievement is BAI. Incremental BAI (the belief that intelligence can be improved by effort) positively influences intrinsic motivation and creativity (Dweck, 1986; Gagné, 2003; Sternberg & Lubart, 1996; Ziegler & Heller, 2000), and entity BAI (the belief that intelligence is fixed and cannot be improved) negatively affects intrinsic motivation and creativity (Deci & Ryan, 1985; Dweck, Malone, & Lepper, 1987).

Within the BAI framework, confidence in intelligence also plays a role in academic achievement (Dweck, 1999; Henderson & Dweck, 1990; Hong, Chiu, Dweck, & Lin, 1998). Confidence in intelligence develops from a variety of influences, such as attendance at a selective school (Ahmavaara & Houston, 2007) or perceived academic performance (Kaplan & Midgley, 1997). It is assumed that students who are confident about their intelligence have an advantage over their less confident peers. However, Dweck argued that confidence in intelligence only predicts success when students are not facing challenges. When students face failure or uncertainty, confidence is not related to persistence or motivation because implicit theories of intelligence are more powerful predictors.

Scientifically talented students were invited to participate in this study in order to understand the influence of various psychological and environmental factors on the creative productivity of former Korean Olympians, because their number is so few that statistical analyses would be limited. Most Olympians attended science high schools (SHS) from tenth to twelfth grades and most SHS students attended science gifted education centers (SGEC). The ratio of Olympians, SHS students, and SGEC students among their peers is 0.002%, 0.01%, and 0.7%, respectively.

Study I explored the differential predictive relationship between perceived positive family processes, intrinsic motivation, incremental BAI, and confidence in intelligence with CPS in mathematics and science of scientifically talented fourth to twelfth graders. Study II examined the predictive relationship among positive family processes, intrinsic and extrinsic motivation, incremental BAI, and confidence in intelligence with CPSMS of scientifically talented individuals in fifth grade, tenth grade, and adulthood (former Olympians).

STUDY I

Participants

A total of 846 students, selected through stratified random sampling throughout Korea, included 303 fourth to sixth graders, 354 seventh to ninth graders from 51 SGECs, and 189 tenth to twelfth graders from 18 science high schools. These students were identified as scientifically talented through a series of identification procedures, including teacher recommendations, test scores on logical thinking and creative problem solving in mathematics and science, and performance tests.

After visual inspection of missing responses, only those with a complete set of data were included for analyses. The final sample size for analyses was 733 (236 fourth to sixth graders, 328 middle-school students, and 169 high-school students), with missing rates per variable ranging from 0.0 to 3.7%. There was no observed systematic pattern among the missing responses. Reliability estimates of the inventories were mostly acceptable, ranging between $\alpha = .71$ and .93 (*Mdn* $\alpha = .83$).

Instruments

Students completed Likert-type scales, the Creative Problem Solving in Mathematics and Science (CPSMS) scale, the Korean Inventory of Parental Influence (KIPI), the Motivation Scale, the Incremental BAI Scale, and the Confidence in Intelligence Scale. The Korean versions of these scales were developed and validated by Cho and Han (2004). Exploratory factor analyses (EFA) on all of the measures were conducted to confirm the subfactors to be examined in this study, and reliabilities were examined by calculating Cronbach's α with the participants' responses (see Table 1). Confirmatory factor analyses (CFA) confirmed the measurement models for the hypothesized latent variables and examined bivariate relationships among the latent variables. Goodness-of-fit and lack-of-fit indices were reported for each inventory.

Creative Problem Solving in Mathematics and Science Scale

Students reported how often they experience CPS when they solve mathematics and science problems on six items (e.g., "I have enjoyed solving mathematics or science problems in unknown ways to public") on a scale from 1 (*never*) to 5 (*always*). Despite the small number of items, reliability was relatively good, with Cronbach's α ranging from .85 to .87. Goodness of fit of the hypothesized model by maximum likelihood factor analysis was reasonably adequate, as seen by the chi-square analysis, χ^2 (43) = 396.2, $p < .001$, and the goodness-of-fit or lack-of-fit indices (GFI = .966, RMR = .049). In general, GFI between .80 and 1.00 and an RMR value approaching .05 supports an adequate to good fit.

Motivation Scale

Students reported their feeling of success on nine items about intrinsic motivation (e.g., "I feel successful when I learn something interesting and engaging") and on eight

TABLE 1
Positive Components of Family Process and Affective Variables in Scientifically Talented Elementary-, Middle-, and High-School Students

Variables	*Group*	*N*	*M*	*SD*	A	*Factor loading*	*F*	*Scheffé*
Intrinsic motivation	Elementary	236	3.98	.53	.77	.240–.704	8.88**	Elementary < Middle*
	Middle	328	4.12	.48	.74			Elementary < High*
	High	169	4.13	.45	.71			
	Total	733	4.07	.50	.75			
Extrinsic motivation	Elementary	236	4.07	.70	.88	.496–828	2.33	
	Middle	328	3.98	.73	.89			
	High	169	3.91	.73	.89			
	Total	733	3.99	.73	.89			
Incremental BAI	Elementary	236	4.02	.61	.75	.446–.716	2.91	
	Middle	328	4.05	.59	.78			
	High	169	3.92	.63	.83			
	Total	733	4.00	.61	.75			
Confidence in intelligence	Elementary	236	3.19	.63	.83	.597–.777	1.80	
	Middle	328	3.10	.70	.86			
	High	169	3.20	.69	.88			
	Total	733	3.14	.68	.81			
Positive family processes	Elementary	236	3.60	.59	.93	.683–.813	0.45	
	Middle	328	3.55	.57	.92			
	High	169	3.56	.53	.91			
	Total	733	3.57	.57	.92			
CPSMS	Elementary	236	3.63	.65	.85	.663–.775	0.53	
	Middle	328	3.58	.69	.87			
	High	169	3.56	.65	.87			
	Total	733	3.59	.67	.86			

$^{*}p < .01$. $^{**}p < .001$.

items about extrinsic motivation (e.g., "I feel successful when I get higher grades than other students") on a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). Cronbach's α ranged from .71 to .77 for intrinsic motivation and .88 to .89 for extrinsic motivation. Goodness of fit for intrinsic motivation χ^2 (27) = 507.67, $p < .001$, GFI = .914, RMR = .071 and extrinsic motivation χ^2 (20) = 582.65, $p < .001$, GFI = .888, RMR = .056 revealed that the model was relatively adequate.

Incremental Beliefs About Intelligence Scale

The Korean version of the BAI Scale was revised by Cho and Han (2004) from a scale developed by Dweck and her colleagues (Dweck, Chiu, & Hong, 1995). Incremental BAI was measured by seven items, three of which were reverse-coded (e.g., "My intelligence is good, but there is nothing much that I can do to improve my intelligence"). The Incremental BAI score is the average rating on the seven items using a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). Reliability of this scale was relatively good, with Cronbach's α ranging from .75 to .83. Goodness of fit demonstrated that the model was reasonably adequate, $\chi^2(14) = 569.02$, $p < .001$, GFI = .872, RMR = .099.

Confidence in Intelligence Scale

This scale was modified from six items initially developed by Dweck (1999) in which students reported the strength of their subjective convictions that their intelligence is high (e.g., "I am confident that I am smart enough to be successful"). Reliability of this scale was relatively good, with Cronbach's α between .83 and .88. Goodness of fit showed that it was reasonably adequate, $\chi^2(20) = 466.304$, $p < .001$, GFI = .905, RMR = .068.

The Korean Inventory of Parental Influence

The Korean version of Campbell's (1994) Inventory of Parental Influence consists of 44 items on six factors. Participants responded from 1 (*strongly disagree*) to 5 (*strongly agree*) on their perceptions of family processes during school years. Family process factors of support (e.g., "My parents respect my decisions."), pressure for intellectual development (e.g., "My parents took me to the library."), parents' discussion (e.g., "When my mom had to decide about my education, she discussed it with my dad."), and father's involvement (e.g., "At home, my father explained about what I asked.") were combined to create an index called Positive Family Processes. Cronbach's α ranged from .91 to .93 with high reliability. CFAs were conducted for each factor and the goodness-of-fit and lack-of-fit indices showed that the model is reasonably adequate, with GFI ranging from .920 to .983 and RMR from .036 to .086. RMR and GFI for each factor were .033 and .975, respectively, for psychological support; .058 and .928, respectively, for pressure for intellectual development; .042 and .956, respectively, for parents' discussion; and .051 and .953, respectively, for father's involvement.

Procedure and Statistical Analyses

This study is part of a Korean national longitudinal study on talent development in science. The Ministry of Education sent letters to 51 science gifted education centers and 18 science high schools in 16 metropolitan areas to request their assistance in securing consent from parents and students and implementing the inventories from a stratified random sampling. Teachers in each center administered, collected, and returned the students' responses to the researchers. Only portions of the national research data relevant to the research questions in this study were analyzed.

One-way analysis of variance (ANOVA) and Scheffé tests were performed with the scientifically talented students pooled together in order to find differences between various pairs of age groups on positive family processes, incremental BAI, confidence in intelligence, intrinsic motivation, and CPSMS. Correlational and stepwise multiple regression analyses examined the relationships among variables related to CPSMS. Multiple regression analyses determined the most effective model of predicting CPSMS among the several predictors.

Structural equation modeling (SEM) analyses tested the comparative utility of perceived family processes in predicting Korean scientifically talented students' CPSMS, along with the mediating roles of students' intrinsic motivation, BAI, and confidence in intelligence. The study examined goodness of fit and lack of fit of the hypothesized model of the relationship among the factors using Analysis of Moment Structures (AMOS) maximum likelihood factor analysis (Hair, Black, Babin, Anderson, & Tatham, 2006) with (a) chi square statistic, (b) goodness of fit index (GFI), (c) normed fit index (NFI), (d) comparative fit index (CFI), and (e) root mean square error of approximation (RMSEA).

Results

Scientifically talented Korean students showed high intrinsic (M = 3.98–4.13) and extrinsic (M = 3.91–4.07) motivation. Specifically, they reported enjoying solving complex problems and studying because of the expectation of various rewards for performance, including recognition from teachers and greater chances for admission into prestigious educational institutions. These scientifically talented students showed high incremental beliefs about intelligence (M = 3.92–4.05), as expected with East Asian students. Surprisingly, confidence in intelligence (M = 3.10–3.20) was not very high, even though these students have been identified as scientifically talented and the ratio of these students to their peers is less than 1%. In addition, relatively high positive family processes (M = 3.55–3.60) and CPSMS (M = 3.56–3.63) were seen in these scientifically talented Korean students.

A developmental trend was shown only in intrinsic motivation, $F(2, 824) = 8.89$, $p < .001$, where middle- and high-school students showed significantly higher intrinsic motivation than elementary-school students. No significant group differences were found on incremental BAI, extrinsic motivation, confidence in intelligence, family processes, and CPSMS among students at the elementary-, middle-, and high-school levels (see Table 1). Other studies have found that as scientifically talented Koreans get older, family support increases, whereas press for intellectual development, father's involvement, and parents' discussions decrease (Cho, Kang, Lee, Han, & Ahn, 2004, 2005). These developmental trends in family processes in opposite directions may have compensated for each other and, when combined together, displayed no significant trends along age-related developmental stages. These findings in Study I may have resulted because the students in continuous grade levels were categorized into three broad groups that may have overgeneralized their developmental characteristics and washed out any possible effects by grade. It may be necessary to compare the group data at more distinct grade levels.

Before testing the predictive relationship among the related variables, bivariate relationships between affective characteristics and positive family processes with CPSMS of all students were examined using Pearson's correlation coefficients. Confidence in intelligence correlated most highly with CPSMS ($r = .40$, $p < .001$), followed by intrinsic motivation ($r = .29$, $p < .001$), positive family processes ($r = .29$, $p < .001$), and incremental BAI ($r = .20$, $p < .001$). Extrinsic motivation did not significantly correlated with CPSMS.

The patterns of these relationships differed by grade level. At the elementary-school level, CPSMS correlated most highly with positive family processes ($r = .40$, $p < .001$), followed by, in descending order, confidence in intelligence, intrinsic motivation ($r = .39$, $p < .001$), extrinsic motivation ($r = .28$, $p < .001$), and incremental BAI ($r = .26$, $p < .001$). At the middle-school level, CPSMS correlated most highly with confidence in intelligence ($r = .40$, $p < .001$), followed by, in descending order, positive family processes ($r = .31$, $p < .001$), intrinsic motivation ($r = .30$, $p < .001$), and incremental BAI ($r = .19$, $p < .001$). However, extrinsic motivation did not significantly correlate with CPSMS. At the high-school level, confidence in intelligence ($r = .41$, $p < .001$) correlated most highly with CPSMS, followed by intrinsic motivation ($r = .13$, $p < .05$) and incremental BAI ($r = .13$, $p < .05$; see Table 2). Extrinsic motivation and family processes did not significantly correlate with CPSMS.

TABLE 2
Zero-Order Correlation Coefficients of Positive Family Processes and Affective Variables With CPSMS by School Level

School level	*Variables*	*1*	*2*	*3*	*4*	*5*	*6*
All ($N = 733$)	1. Family processes	—					
	2. Confidence in intelligence	.25***	—				
	3. Incremental BAI	.32***	.22***	—			
	4. Intrinsic motivation	.32***	.20***	.31***	—		
	5. Extrinsic motivation	.20***	.27***	.22***	.41***	—	
	6. CPSMS	.29***	.40***	.20***	.29***	.14	—
Elementary ($N = 236$)	1. Family processes	—					
	2. Confidence in intelligence	.31***	—				
	3. Incremental BAI	.35***	.32***	—			
	4. Intrinsic motivation	.40***	.26***	.33***	—		
	5. Extrinsic motivation	.17**	.37***	.27***	.42***	—	
	6. CPSMS	.40***	.39***	.26***	.39***	.28***	—
Middle ($N = 328$)	1. Family Processes	—					
	2. Confidence in intelligence	.29***	—				
	3. Incremental BAI	.34***	.23***	—			
	4. Intrinsic motivation	.30***	.21***	.33***	—		
	5. Extrinsic motivation	.18**	.26***	.25***	.43***	—	
	6. CPSMS	.31***	.40***	.19***	.30***	.08	—
High ($N = 169$)	1. Family processes	—					
	2. Confidence in intelligence	.07	—				
	3. Incremental BAI	.25***	.11	—			
	4. Intrinsic motivation	.30***	.09	.27***	—		
	5. Extrinsic motivation	.30***	.16*	.09	.45***	—	
	6. CPSMS	.07	.41***	.13*	.13*	.08	—

*$p < .05$. **$p < .01$. ***$p < .001$.

Multiple regression analyses of responses from all students showed that confidence in intelligence explained 16% of the variance in CPSMS $F(1{,}731) = 135.10$, $p < .001$. Explained variance increased to 20 and 22% when intrinsic motivation $F(2{,}730) = 91.94$, $p < .001$ and positive family processes $F(3{,}729) = 68.88$, $p < .001$, respectively, were entered into the model.

Multiple regression analyses of scientifically talented elementary school students showed that positive family processes explained most of the variance (16%) in CPSMS $F(1{,}234) = 45.33$, $p < .001$. The addition of confidence in intelligence and intrinsic motivation into the model increased the explained variance to 23% $F(2{,}233) = 36.98$, $p < .001$ and 28% $F(3{,}232) = 30.76$, $p < .001$, respectively. For middle-school students, confidence in intelligence explained most of the variance (15%) in CPSMS $F(1{,}326) = 60.48$, $p < .001$. When intrinsic motivation $F(2{,}325) = 41.53$, $p < .001$, positive family processes $F(3{,}324) = 31.39$, $p < .001$, and extrinsic motivation $F(4{,}323) = 25.53$, $p < .001$ were entered into the model, 20, 22, and 23%, respectively, of the variance in CPSMS was explained. For high-school students, confidence in intelligence was the single predictor of CPSMS, with 16% of its variance explained $F(1{,}165) = 32.86$, $p < .001$.

It can be inferred that positive family processes is very important for young students to frequently practice CPSMS. With age, one's confidence in intelligence becomes more influential to CPSMS than other affective characteristics or family processes. Based on previous studies (Campbell, 1996; Verna & O'Connor-Petruso, 2008), positive family processes seem to contribute to building intrinsic motivation and confidence in intelligence. In turn, enhanced personal confidence in intelligence and intrinsic motivation contribute to one's frequency of involvement in CPS.

Based on the developmental trend found from the multiple regression analyses in this study, theories, and previous findings related to CPS, the comparative utility of two models with slightly different intervening variables for predicting CPSMS was tested by SEM (Hair et al., 2006). It was hypothesized that positive family processes would predict CPSMS directly and indirectly with mediation of affective characteristics (intrinsic motivation, incremental BAI, and confidence in intelligence), which would, in turn, explain the variances in CPSMS. The first model (see Figure 1) was constructed based on the assumption that influence from contextual perceptions of students on academic behavior are mediated by personal characteristics (Bong, 2008; Patrick, Ryan, & Kaplan, 2007) and from

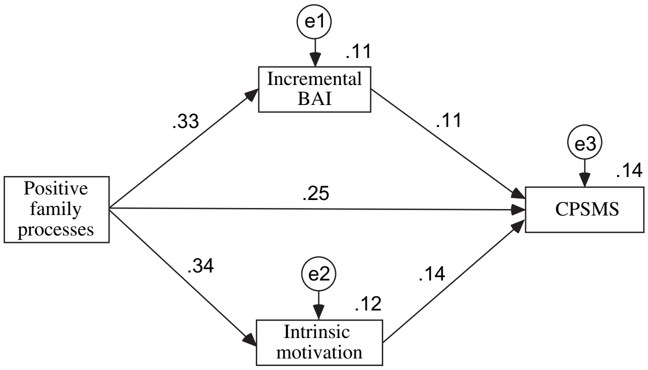

FIGURE 1 Structural equation modeling on the effect of positive family processes, incremental BAI, and intrinsic motivation on creative problem solving in mathematics and science ($N = 733$).

previous findings showing a direct impact of positive family processes on mathematics achievement (Campbell & O'Connor-Petruso, 2008; Campbell & Wu, 1994; Cho, Ahn, & Han, 2004; Simonton, 1987) and the effects of intrinsic motivation (Hennessey & Amabile, 1988; Simonton, 2000) and incremental BAI on creativity (Alpay & Ireson, 2006). Therefore, a direct path from positive family processes to CPSMS and an indirect path through two intervening parameters (intrinsic motivation and incremental BAI) to CPSMS were included in the first model. SEM showed that the first model is not appropriate $\chi^2(43) = 96.831$, $p < .001$, GFI = .964, NFI = .836, CFI = .836, RMR = 1.544 and needed for further improvement, because GFI, NFI, and CFI were far from being close to 1 and RMR was > .05.

A slight modification was made by replacing incremental BAI with confidence in intelligence (see Figure 2). Confidence in intelligence was not considered in the first model because many studies on BAI have not often demonstrated high predictability of confidence in intelligence. However, older students' CPSMS was highly correlated with confidence in intelligence and was in the prediction model when multiple regression analyses were conducted. SEM of the final model with the responses of all students demonstrated that the new model significantly improved goodness-of-fit indices compared to the first model, $\chi^2(43) = 396.2$, $p < .001$, GFI = .997, NFI = .989, CFI = .990, RMR = .016, with GFI, NFI, and CFI close to 1 and RMR less than .05. Figure 1 shows both models with path coefficients among the latent variables that were statistically significant ($p < .05$). More importantly, this is considered to be a more valid representation of the observed covariance structure.

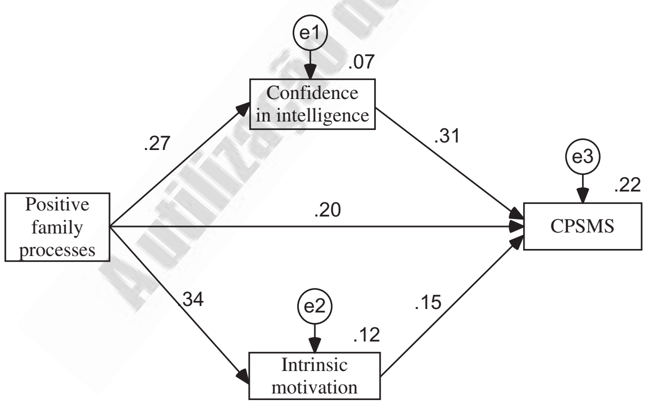

FIGURE 2 Structural equation modeling on the effect positive family processes, confidence in intelligence, and intrinsic motivation on creative problem solving in mathematics and science ($N = 733$).

Confidence in intelligence was the strongest predictor ($r = .31$) of CPSMS, followed by family processes ($r = .20$) and then intrinsic motivation ($r = .15$). Positive family processes predicted intrinsic motivation ($r = .34$) and confidence in intelligence ($r = .27$). These results can be interpreted as positive family processes augmenting CPSMS directly. In addition, positive family processes enhance the intervening variables of confidence in intelligence and intrinsic motivation, which, in turn, increase the frequency of CPSMS of scientifically talented Korean students.

STUDY II

Study II examined the developmental trend with data from past Korean Olympians and scientifically talented Korean students at more distinctive grade levels than in Study I, which included students in continuous grades. The predictive relationship of family processes, motivation, and BAI on CPSMS of scientifically talented individuals was tested. It is hypothesized that the predictive relationships among the related variables would demonstrate a very similar pattern but to different degrees compared to findings in Study I.

Participants

Using stratified random sampling, data from 26 fifth graders from 22 science gifted education centers and 22 tenth graders from 13 science high schools were selected among a subset of participants in Study I. Of the 120 past Korean Olympians, 25 between the ages of 17 and 34 agreed to participate in the study. Among them, 22 (88%) are graduates from science high schools. After visual inspection of missing data, only those with a complete set of data were included for analyses. The final sample size was 71, with 24 fifth graders, 22 tenth graders, and 25 former Olympians. In order to form a large enough age interval between groups, the mean age of the Olympians ($M = 20.7$) was considered in the grade level selection of the other two grade-level groups such that fifth and tenth graders were chosen for an approximately 5-year mean age difference among the three groups. The 5-year mean age of the elementary, high-school, and adult groups were 10.3, 15.4, and 20.7, respectively.

Procedures and Statistical Analyses

The procedure for data collection for the fifth graders and tenth graders was the same as described in Study I. Questionnaires to the former Olympians were sent either through regular mail or electronically and returned individually, because they reside in various places throughout the world. The Olympians were extensively tracked via various means because some of their information differed from what was provided. Five randomly selected parents from each group of participants were interviewed to verify the accuracy of their children's responses. To determine whether group differences exist, one-way ANOVA and Scheffé tests were performed. Correlational and stepwise multiple regression analyses determined significant predictors of CPSMS and the relative contributions of each significant predictor in explaining the variance in CPSMS.

Results

The averages of each variable for scientifically talented Korean students and Olympians were similar with those found in Study I, but average scores at each grade had wider ranges, as expected (see Table 3). Their means on intrinsic motivation, extrinsic motivation, and incremental BAI were quite high, whereas their means on confidence in intelligence, positive family processes, and CPSMS were slightly higher than the midpoint (3.0).

Developmental Trends

Significant group differences were found among the three groups on intrinsic motivation $F(2,68) = 5.52$, $p < .05$, confidence in intelligence $F(2,68) = 3.55$, $p < .05$, incremental BAI $F(2,68) = 6.53$, $p < .01$, positive family processes $F(2,68) = 3.34$, $p < .05$, and CPSMS $F(2,68) = 3.44$, $p < .05$ but not on extrinsic motivation.

Developmental trends were analyzed with Scheffé tests (see Table 3). Tenth-grade students and former Olympians showed higher intrinsic motivation and confidence in intelligence than fifth-grade students, similar to what was found in previous studies (Ablard & Mills, 1996; Leondari & Gialamas, 2002). This is understandable in that older individuals preparing for the Olympiads and admission into science high schools should have more successful experiences in solving challenging open-ended and ill-structured problems, which increased their intrinsic motivation.

Olympians believed less in the incremental nature of intelligence than tenth graders. The Olympians may have experienced a limit on their efforts in improving intellectual ability while participating at the apex of mathematics and science competitions such as the International Olympiads. Olympians showed the highest CPSMS. Likely, as members of the workforce or as graduate students, they have more opportunities to practice CPS with real problems than do high-school students.

TABLE 3
Positive Family Processes and Affective Characteristics of Scientifically Talented Fifth- and Tenth-Grade Students and Olympians

Variables	*Group*	*N*	*M*	*SD*	*α*	*F*	*Scheffé*
Intrinsic motivation	Grade 5	24	3.78	.61	.36	5.52*	Grade 5 < Grade 10*
	Grade 10	22	4.22	.49	.84		Grade 5 < Olympians*
	Olympians	25	4.16	.44	.77		
	Total	71	4.04	.55	.74		
Extrinsic motivation	Grade 5	24	4.02	.73	.87	1.24	
	Grade 10	22	3.81	.67	.89		
	Olympians	25	4.11	.66	.89		
	Total	71	3.98	.69	.88		
Incremental BAI	Grade 5	24	4.00	.53	.96	3.55*	Grade 10 > Olympians*
	Grade 10	22	4.11	.48	.80		
	Olympians	25	3.73	.52	.70		
	Total	71	3.95	.53	.89		
Confidence in intelligence	Grade 5	24	3.31	.64	.92	6.52**	Grade 5 < Olympians *
	Grade 10	22	3.11	.54	.86		Grade 10 < Olympians*
	Olympians	25	3.81	.83	.92		
	Total	71	3.41	.74	.91		
Positive family processes	Grade 5	24	3.54	.61	.80	3.34*	
	Grade 10	22	3.61	.56	.96		
	Olympians	25	3.22	.53	.91		
	Total	71	3.43	.59	.93		
CPSMS	Grade 5	24	3.57	.62	.78	3.44*	Grade 10 < Olympians*
	Grade 10	22	3.40	.62	.63		
	Olympians	25	3.87	.66	.70		
	Total	71	3.61	.66	.70		

*$p < .05$. **$p < .01$.

Tenth graders showed the lowest confidence, the highest incremental BAI, and the highest positive family processes compared to fifth graders and past Olympians. This is logical, because they are attending science high schools, where more talented students study together than in their elementary- and middle-school periods. They are also under extremely intense pressure, anticipating rigorous competition in university admissions. Because admittance into a university will make a big difference in these students' future status and salaries in Korea, families employ any means to support them to do their best and, consequently, these students are more likely to believe that greater effort will yield higher grades (Sorensen, 1994). No significant developmental trends were shown on positive family processes.

Correlation coefficients of the 71 participants' CPSMS were significantly high on confidence in intelligence ($r = .52$, $p < .001$) and intrinsic motivation ($r = .25$, $p < .05$). Further examination of the relationships between CPSMS and affective factors (motivation, BAI, and confidence in intelligence) and positive family processes showed that the relationships were quite different depending on the developmental stage. For scientifically talented fifth graders, CPSMS correlated most highly with confidence in intelligence ($r = .59$, $p < .05$), followed by intrinsic motivation ($r = .39$, $p < .05$) and positive family processes ($r = .39$, $p < .05$). For scientifically talented tenth graders, only confidence in intelligence ($r = .74$, $p < .001$) was significantly correlated with CPSMS. For former Olympians, none of the variables was significantly correlated with CPSMS (see Table 4).

Multiple regression analysis of the 71 scientifically talented students and Olympians showed that the only significant predictor of CPSMS was confidence in intelligence, which explained 27% of its variance ($F[1,69] = 25.02$, $p < .001$). Similar results were found with fifth graders, where confidence in intelligence was the only significant predictor of CPSMS, explaining 31% of its variance $F(1,22) = 11.53$, $p < .001$. For tenth graders, the variance explained by confidence in intelligence was 53% $F(1,20) = 11.53$, $p < .001$, which was greater than that of fifth graders and that of former Olympians. When extrinsic motivation entered into the model, the variance explained increased to 63% $F(2,19) = 19.04$, $p < .001$. For the Olympians, none of the variables were found to be significant predictors of CPSMS.

TABLE 4
Zero-Order Correlation Coefficients Between Positive Family Processes, Affective Variables, and CPSMS of Scientifically Talented Fifth- and Tenth-Grade Students and Olympians

School Level	*Variables*	*1*	*2*	*3*	*4*	*5*	*6*
All ($N = 71$)	1. Family processes	—					
	2. Confidence in intelligence	.06	—				
	3. Incremental BAI	.32***	−.1	—			
	4. Intrinsic motivation	.31***	.23**	.43****	—		
	5. Extrinsic motivation	.17	.27**	.09	.23**	—	
	6. CPSMS	.13	.52****	.09	.25**	.09	—
Grade 5 ($N = 24$)	1. Family processes	—					
	2. Confidence in intelligence	.45**	—				
	3. Incremental BAI	.32	.45**	—			
	4. Intrinsic motivation	.48***	.52***	.48***	—		
	5. Extrinsic motivation	.04	.51***	.22	.13	—	
	6. CPSMS	.39**	.59***	.18	.39*	.16	—
Grade 10 ($N = 22$)	1. Family processes	—					
	2. Confidence in intelligence	.41**	—				
	3. Incremental BAI	.14	.33	—			
	4. Intrinsic motivation	.51***	.48**	.63***	—		
	5. Extrinsic motivation	.28	.34	−.12	.28	—	
	6. CPSMS	.26	.74****	.35	.29	−.07	—
Olympians ($N = 25$)	1. Family processes	—					
	2. Confidence in intelligence	−.10	—				
	3. Incremental BAI	.23	−.47***	—			
	4. Intrinsic motivation	.05	−.18	.39**	—		
	5. Extrinsic motivation	.43**	−.07	.31	.45**	—	
	6. CPSMS	.09	.21	.10	.06	.06	—

*$p < .05$. **$p < .01$. ***$p < .001$.

DISCUSSION AND IMPLICATIONS

Scientifically talented Korean students displayed very high incremental BAI, intrinsic motivation, and extrinsic motivation. High incremental BAI suggests the influence of Confucian philosophy and culture in Korean students, where not only young students but also older students believed in the malleability of their intelligences (Cho, 2007; K. H. Kim, 2005b; Lee, 2005; Wu, 1996). High extrinsic motivation was also expected in the Korean context where family members value education as the only path to success (Sorensen, 1994; Watkins & Biggs, 1996) and where only education justifies differential status and salary (Sorensen).

However, high intrinsic motivation was unexpected because Korean students' attitudes and self-concepts in mathematics ranked 43rd among 49 countries in the Program for International Student Assessment (PISA) study (Organisation for Economic Co-operation and Development [OECD], 2004), suggesting that the competitive educational environment in Korea (Bong, 2008) has not attenuated the intrinsic motivation of the scientifically talented. The Korean gifted identification system, which focuses on CPS ability in identification (Cho, 2000, 2004), and the gifted education curriculum may have contributed to the students' high intrinsic motivation and CPSMS (Seo, Cho, Kim, & Jeong, 2003). The developmental trend on intrinsic motivation is that the longer they participate in the gifted education program, the higher their intrinsic motivation becomes.

Unexpectedly, confidence in intelligence of scientifically talented students was also not very high. This was a surprising result considering their exceptional science talent. One reason may be that these students are influenced by the Confucian culture, which emphasizes humility and modesty. Their humility enabled them to modestly express their beliefs about their own intelligence. Another possible reason is the phenomenon of "a small fish in a big pond" (Marsh, 1989) in which they are among similarly highly talented peers in gifted education institutions.

As in any survey research, it is not possible to claim causal relationships based on correlational patterns among variables. Despite such limitations, the present results suggest that some potential mechanisms of students' perceptions on their family processes under a Confucian culture translate into motivation, confidence in intelligence, and CPSMS. In particular, findings from this study confirm the critical function of family processes in ushering students to CPSMS directly, as well as indirectly by enhancing intrinsic motivation and confidence in intelligence.

The causal paths among these factors showed that confidence in intelligence predicts CPSMS better than any other variables, regardless of age. These findings suggest that scientifically talented Korean students, with support and encouragement from family, believe in the possibility of improving intelligence. With an incremental belief about intelligence, they work hard and experience repeated success, which increases their confidence in intelligence in the future. Those with higher confidence may take more risks in solving problems in mathematics and science. However, once they experience a limit in their effort to improve their performance in CPS, their belief in the incremental nature of intelligence decreases, as shown with the former Olympians.

The developmental trend showed that family processes or confidence in intelligence was the best predictor of CPSMS for elementary school students. However, for secondary-school students, the best predictor was confidence in intelligence. Intrinsic motivation was a weak predictor for CPSMS for elementary- and middle-school students. These findings differ from other studies that reported incremental BAI or intrinsic motivation as the best predictor of creativity or achievement (Amabile, 1983, 1996; Csikszentmihalyi, 1990; Cho, Han, et al., 2005; Deci & Ryan, 1985; K. H. Kim, 2005a; Malone & Lepper, 1987; Moneta & Siu, 2002), but are consistent with Dweck (1999) who argued that when children are not facing failure, confidence in intelligence is a better predictor of success.

Another reason for these findings may be due to the unique characteristics of the participants and the domain of discipline examined in this study. Most participants in previous studies were randomly selected students with a wide range of intellectual abilities, whereas participants in this study were highly talented students in mathematics and science. An essential component of high CPSMS may be high confidence in intelligence (Amabile, 1996; Sternberg & Lubart, 1996; Urban, 1995), which implies that confidence in intelligence should be strengthened through repeated experiences of success in academic activities to acquire family support as well as encouragement and involvement with their children.

The strong predictability of confidence in intelligence on CPSMS and its developmental trend may be the result of the developmental process of expertise in CPSMS (Sternberg & O'Hara, 1999). Creative individuals produce new ideas from a large set of well-developed skills and a rich body of domain-relevant knowledge (Simonton, 2000; Weisberg, 1999), which develop through deliberate practice over time (Ericsson, 1996; Gardner, 1993; Simonton, 1994). Challenging experiences during deliberate practice may help strengthen a person's confidence in intelligence and capacity to persevere in the face of obstacles (Simonton, 1994).

Statistical analyses on data of the former Olympians were limited because of the small number of participants. None of the predictors were significantly related or were significant predictors of CPS for the Olympians, unlike the findings for elementary- and secondary-school students. Although their confidence in intelligence was highly correlated with CPSMS, it was not a significant predictor of CPSMS. The common characteristic these Olympians shared was that they won awards at International Mathematics or Science Olympiads. However, they included high-school students, graduate students, and those who are now in the workforce, so it may not be valid to place them into one group for quantitative scrutiny. It can also be interpreted that the significant predictors for scientifically talented Korean students are different from the predictors for adult Olympians. As suggested in previous studies, mentoring (Campbell, 1996; Zuckerman, 1977), peer recognition of significant contributions (Merton, 1957), or a houndstooth model (Renzulli, Sytsma, & Berman, 2000) should be studied further as possible significant predictors to the productivity of Olympians who are at the peak of their performances in creative problem solving.

LIMITATIONS

Some limitations of this study should be kept in mind when interpreting and comparing these findings with other studies. For instance, CPSMS is not a performance test score but a self-reported index of creative problem solving in Mathematics and science. The participants are scientifically talented students and do not represent all gifted students in Korea. In addition, most of the instruments used to measure affective traits were self-report scales specifically designed for Korean students. The affective inventories were domain free and did not refer to affective characteristics in Mathematics or science. Next steps include examining how these predictive relationships change when BAI and motivation are restricted to the Mathematics domain and in other domains such as art and music.

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