MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2023, 19(7), em2288
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/13274

Investigation of a developmental path model for interest in the study of mathematics

Joo Hyun Park [1], Sunyoung Han [1*]

[1] Department of Mathematics Education, Sungkyunkwan University, Seoul, SOUTH KOREA

Received 09 March 2023 ▪ Accepted 28 April 2023

Abstract

In this study, we investigated a developmental path model for interest in the study of mathematics and confirmed that interest in learning mathematics developed significantly from situational into individual interest. We also present results showing that revealed individual interest (RII) influenced students' academic achievement as a mediating effect, although their potential individual interest (PII) did not directly affect achievement in mathematics. Finally, based on an identified developmental path model, a multigroup analysis was conducted to analyze differences along lines of gender and grade levels. The result showed a significant difference in the effect of RII on academic achievement in mathematics by gender and grade levels, and an effect of PII on RII by grade levels. These findings provide public and private education with implications for motivating students and maintaining their interest in mathematics.

Keywords: mathematical interest, interest development, situational interest, individual interest, private education

INTRODUCTION

Humans experience their physical, emotional, and cognitive development both quantitatively and qualitatively throughout their entire lives. This development mostly signifies a positive change from lesser to greater stages of capacity and understanding (Mussen et al., 1969). Human development occurs sequentially at different speeds for each individual, and changes primarily occur gradually rather than suddenly. Bloom (1985) proposed that educational activities affect students' development through cognitive, psychodynamic, and affective domains.

Out of these three domains, education in Korea has mainly focused on the examinations administered for entering universities and has thus, in turn, emphasized students' cognitive development. One of the key features of education in Korea is curriculum acceleration at private institutes, which may be the result of Korean education overemphasizing only the cognitive development. Due to the predominance of early advanced learning, Korean students may exhibit higher academic achievement than those in the other countries according to international evaluations such as program for international student assessment (PISA) and trends in international mathematics and science study (TIMSS). The Korea Institute of Curriculum Evaluation released a statement in 2016 declaring that Korean students' math achievement at TIMSS 2015 was still the highest, but that their rankings had slipped relative to the TIMSS scores achieved by Korean students in 2011. It may be inferred from this fact that the development of the affective domain of Korean students still remains at a low level (Choe et al., 2014; Park & Rim, 2014).

As such, this study focused on the affective factor that teachers consider the most important, which are students' levels of interest in studying mathematics (Choi & Han, 2013; Kim & Jeon, 2013). Although interest in mathematics is an important variable that teachers consider in classes, previous studies related to interest in mathematics have been limited. According to the previous research, "interest" can be categorized as situational or individual interest, and it has been reported that situational interest tends to develop into particular individual interest (Hidi & Renninger, 2006; Kim, 1996; Krapp, 2002; Linnenbrink-Garcia et al., 2010). However, studies on interest in mathematics have mainly analyzed changes in students' interest resulting from the application of teaching and learning methods

✉ 2tjw40@uos.ac.kr ✉ sy.han@skku.edu **(*Correspondence)**

Contribution to the literature

- The extracurricular-related situational interest develops into potential individual interest through the mediation of curricular-situational interest.
- The curricular-situational interest develops into revealed individual interest through the mediation of potential individual interest.
- The potential individual interest influences the academic achievement in mathematics, which is mediated by revealed individual interest.

(Do & Choi, 2011; Na & Son, 2016). In addition, although students' interest is a major variable influencing their cognitive development (Krapp & Prenzel, 2011; Rotgans & Schmidt, 2017), research on the development of interest remains insufficient, so data are not abundantly available to understand the relationship between interest and academic achievement in mathematics (Choe & Lee, 2005; Choi & Sang, 2019; Hwang & Lew, 2018; Ju et al., 2011; Kim & Jeon, 2013; Park, 2015). A path model that can describe how students' interest in a specific subject, mathematics, develops is needed, and this study aims to explore this.

Moreover, studies on the effect of mathematical interest on academic achievement were very limited. Although some previous studies (e.g., Heinze et al., 2005; Kim et al., 2021) reveal that there is a relationship between mathematical interest and academic achievement in mathematics, studies that have revealed the causal relationship between mathematical interest and academic achievement in mathematics are very limited. In addition, in some studies (e.g., Rotgans & Schmidt, 2017; Chung et al., 2014; Shin & Park, 2012) reporting that mathematical interest can affect mathematics academic achievement, there was a tendency to fail to consider detailed sub-factors of mathematical interest when measuring it. That is, there are very few studies that reflect the fact that mathematical interest is divided into situational interest and individual interest, and that situational interest and individual interest can be divided again into sub-elements. However, closely grasping the sub-elements of mathematical interest would be important in designing educational activities.

Therefore, based on consideration of the sub-elements of mathematical, this study sought to explore the path model interest and to identify the relationship between mathematical interest and academic achievement. In addition, how these relationships differ according to the gender and grade of the students was explored. Students' gender and grade have been reported as major factors influencing mathematical interest (Kim & jeon, 2013; Lee & Song, 2011; Lew & Hwang, 2019). In other words, the factors of gender and grade that affect students' mathematical interest can also influence the path to be explored in this study, so it was necessary to explore them. To pursue these research aims, the current study used the four sub-elements of interest in learning mathematics (i.e., extracurricular-related situational interest [ESI], curricular-related situational interest [CSI], potential individual interest [PII], and revealed individual interest [RII]), which was classified by Park et al. (2019). With these four sub-elements of mathematical interest, we investigated how interest in mathematics develops (e.g., from situational to individual interest) and how interest is related to students' achievement in mathematics. Additionally, based on these relationships, we conducted a multigroup analysis to examine the identified relationships among the mathematical interest factors according to gender and grade levels. For this purpose, we investigated the following questions.

1. **RQ1.** How does interest in learning mathematics develop and how does it relate to academic achievement in mathematics?
   a. **RQ1.1.** How do ESI, CSI, PII, and RII affect each other and what developmental paths do they represent?
   b. **RQ1.2.** What is the relationship between the interests in learning mathematics and academic achievement in mathematics?
2. **RQ2.** According to the student's features such as gender and grade level, how different are the relationships between the interest in learning mathematics and academic achievement in mathematics?

LITERATURE REVIEW

In educational terms, interest can be divided into situational and individual interests. This is based on the premise that interest in general develops from situational interest into individual interest (Hidi, 1990; Hidi & Baird, 1986; Kim, 1996; Krapp, 2000; Renninger et al., 1992; Schiefele, 1991; Wiśniewska, 2013). Park et al. (2019) developed an instrument to measure students' overall interest in learning mathematics and proposed that mathematical interest may be categorized into four sub-elements, including ESI, CSI, PII, and RII. ESI is generated from activities other than the curriculum, which are conducted as part of the course of formal education, and in this paper, we limit our use of the term to creative-practicum activities. Also, CSI refers to interest related to emotions generated in a mathematics subject class. Next, PII represents that students perceive

Table 1. Items measuring RII

Seo (2012)	Park et al. (2019)
□ I like mathematics.	□ I like mathematics.
□ I like to do mathematics assignments before other assignments.	□ I wish I did not have to study mathematics.
□ I like reading books about mathematics.	□ I like solving mathematics problems.
	□ My attitude toward mathematics is positive.
	□ I am engrossed in studying mathematics.
	□ I have a hard time with mathematics.

the importance and value of learning mathematics and feel the need to engage in follow-up learning in the future. Finally, RII refers to feeling and attitudes toward current learning in mathematics and continuing efforts in the future. Essentially, individual interest refers to interest on a personal level in a specific topic or activity in a subject, whereas situational interest refers to a shared interest in a particular topic or stimulus in a learning context (Hidi & Renninger, 2006; Krapp , 2002). Personal interest is again divided into potential interest and realized interest, depending on whether it refers to the level of recognizing the personal value of mathematics or to the level of continuous effort based on it (Schraw & Lehman, 2001). In addition, situational interest is divided according to whether the interest is aroused in a curricular learning situation or an extracurricular situation (Park et al., 2019).Through the use of these four sub-elements of interest, we aimed to formulate a developmental path model of interest in learning mathematics and shed light on the relationship between interest in learning mathematics and academic achievement in mathematics.

Developmental Path Model of Interest in Learning Mathematics

How ESI can influence PII

ESI is a variable affecting PII. Extracurricular activities include not only creative-practicum activities designed to develop students' creativity, but also various activities providing the students with awards, certifications, qualifications, and records for reading books. According to Lee (2019), however, except for creative-practicum, other activities can be experienced in the subject classes or through the practicum activities. In this context, extracurricular activities can be regarded as an educational term for creative-practicum activities. Therefore, we define extracurricular activities to refer exclusively to creative-practicum activities in the present work.

Previous studies have reported that extracurricular activities stimulate and increase students' interest in the subject (Seon et al., 2007). For example, Seon et al. (2007) analyzed that students who experience a variety of activities related to career exhibited positive attitudes toward occupational value. Occupational value can be referred to as an increase in the recognition of the value of career-related learning through deep contemplation and reflection on one's own potential future career. As another example, through science classes that emphasize creative-practicum activities, Kim and Kim (2014) showed that students changed their attitudes toward science by participating in science clubs. The result showed that students exhibited interest in science-related jobs while attending activities using scientific equipment. Furthermore, the researchers revealed that students realized the importance of studying science with experiences in science clubs. As such, the activities related to career in Seon et al.'s (2007) study and participating in science clubs in Kim and Kim's (2014) study were extracurricular activities, and the recognition of the value of career-related learning and the importance of studying science could be regarded as PII in that it reveals an individual's interest in a specific subject. Therefore, we could conclude that extracurricular activities regarding mathematics might affect students' PII by helping them recognize the value of future learning.

Moreover, a study by Park and Han (2021) identified types of extracurricular activities that encouraged students to develop more interest in learning mathematics. They also found that students were interested in learning mathematics while taking lectures from an expert in mathematics or when understanding the need for mathematics for their desired occupations while participating in career-building activities. Therefore, it could be inferred that participating in career-related extracurricular activities drove students to experience PII, enabling them to recognize the importance and value of learning the subject.

How ESI can influence RII

ESI experienced in creative-practicum activities also affects RII. For example, Seo (2012) reported that high school mathematics programs employing creative-practicum activities resulted in positive changes to students' levels of interest in learning mathematics. When comparing the two measuring instruments, as shown in **Table 1**, the items employed by Seo (2012) included the concept of RII from Park et al. (2019), which considered both emotions and attitudes toward current learning in mathematics, and ongoing commitment to mathematics in the future. Therefore, it may be concluded that ESI has a positive effect on RII.

In contrast to the previous analyses, ESI did not show any positive effect on RII in some works. Luthar and

Table 2. CSI questions

Park (2012)
□ I enjoy my time studying mathematics.
□ I look forward to mathematics class.
□ I wish I had more time to study mathematics.
□ I do not mess around with students in mathematics class.
□ I like to do presentations in mathematics class.

Sexton (2004) argued that the purpose of attending extracurricular activities may be nothing more than providing a means of information-gathering for detailed school reports and student records. Ultimately, if students are excessively exposed to extracurricular activities that are not appropriate for the purposes and contents of academic activities, these activities may not have any meaningful impact on their learning (Marsh, 1992; Marsh & Kleitman, 2002). Although the number of empirical studies supporting this theory may be considered insufficient (Mahoney et al., 2006), some studies have proposed that creative-practicum activities may affect RII in some cases or may not in some others (Seo, 2012). For example, a study by Kim and Kim (2014) reported that most students increased their interest in science and science classes through creative-practicum activities. In contrast, they proposed that some students did not change their levels of interest and some even lost interest in science. The researchers measured students' interest in science and in learning science with survey items such as "I am interested in science," "I like reading books on scientific topics," "I want to learn new scientific knowledge," etc. These items are similar to the items measuring RII developed by Park et al. (2019) because they were all designed to measure the students' emotions and attitudes toward the subject and evaluate their continuous efforts to achieve the given goals for the subject, despite the difference in the subjects. In the end, interest encouraged by extracurricular activities may exhibit positive or negative effects on students' RII and sometimes, does not have any effect on their RII improvement. With this theoretical foundation, the theory of Kim and Kim (2014) may be applied to examine the students' interest in mathematics.

How ESI can influence CSI

Several studies have reported that ESI could exhibit a positive effect on CSI. Choi and Kim (2020) analyzed how science education outside the classroom can affect the students' interest in science and their attitudes toward the subject. The result showed that participating in activities based on creative-practicum outside the classroom considerably increased their expressed interest in science. The researchers measured students' interest in science with survey items such as "I enjoy science class," "It is fun to study scientific knowledge or theory," "It is interesting to do experiments or observe and explore," "It is fun to do hands-on activities (production of items, drawing posters)," and "It is good to discuss (question and response) and do presentations." These items measured not only the students' interest in studying science in class, but also their interests as motivated by activities such as inquiry, discussion, and presentation. Thus, these items may be considered to measure students' CSI. In addition, Bae (2018) found that both students and teachers could be passive about extracurricular activities such as creative-practicum activities in the current curriculum and considered that they emphasize only entrance examination for universities. To address this issue, he conducted a study combining geography lessons and creative-practicum activities. The result of his approach of connecting geography class with the problem-centered learning of the practicum activities showed that the students became more aware of the importance of geography through the practicum. Also, the study concluded that CSI, emotion, and feeling affect the students' engagement and experience in class and improved their effect.

Park (2012) conducted quantitative research on changes in high school students' attitudes after participating in a creative-practicum-focused mathematics club. Out of the items measuring their attitudes toward mathematics, those in **Table 2** show the students' positive changes after engaging in activities with a mathematics club. These items can measure the features of interest that can occur in a mathematics class and therefore, also measure the students' CSI. Thus, it may be concluded that ESI encouraged by creative-practicum activities also affects CSI in mathematics classes.

How CSI can influence PII

CSI stimulated through various teaching and learning methods in mathematics classes may exhibit a positive effect on PII. Na and Son (2016) proposed that a reading-based approach to teaching mathematics in different grade levels had a positive effect on the development of students' affective domains. Park and Han (2019) reported that a method of project-based learning showed a significant effect on the learners' affective characteristics for studying mathematics. Both these studies emphasized the importance of understanding the value of studying mathematics as a factor predicting the formation of affective characteristics in students and the items shown in **Table 3**. The items measured the perceived value of studying mathematics as well as the necessity and usefulness of studying the subject in daily life. These items contain the elements of PII classified by Park et al. (2019). Therefore, CSI can be predicted as influencing PII.

How CSI can influence RII

Some studies have found that CSI can affect not only PII but also RII and can thus, represent the students'

Table 3. Items measuring PII

Na & Son (2016)	Park & Han (2019)
□ Mathematics can solve problems in everyday life. □ Mathematics is a subject worth studying. □ I need mathematics to learn other subjects.	□ Mathematics can solve problems in everyday life. □ Mathematics is a subject worth studying. □ I need mathematics to learn other subjects. □ Mathematics can help me get the job I want. □ I study mathematics to get the job I want.

Table 4. RII items 1

Do & Choi (2011)	Cho & Kim (2013)	Na & Son (2016)
□ I enjoy mathematics class.	□ I enjoy studying mathematics.	□ I like mathematics.
□ I think I need to study mathematics a lot.	□ I feel bored with mathematics.	□ Mathematics is a boring subject for me.
□ I think I should be good at mathematics.	□ I like mathematics.	□ Mathematics becomes more fun more I study it.

current emotions and attitudes toward learning mathematics (Cho & Kim, 2013; Do & Choi, 2011; Na & Son, 2016). To increase the students' CSI in studying mathematics, Do and Choi (2011) employed mathematical modeling problems in classes, and Cho and Kim (2013) adopted a collaborative learning approach. The results showed that these two methods had significant effects in terms of improving students' levels of interest. Survey items of these studies are presented in **Table 4**. They can measure the students' RII because the statements of the items express positive and negative emotions about mathematics as well as their attitudes toward learning in the future.

How PII can influence RII

Recognizing the usefulness, necessity, and value of studying mathematics motivates students to feel interested in mathematics itself. Hidi and Renninger (2006), who compared CSI and levels of individual interest, said that in order to maintain CSI, having positive emotions about the objects is important. Moreover, they argued that the learners should recognize the value of performing their given tasks and activities. They also said that the learners' individual interest can be induced and maintained while recognizing the value of conducting the tasks repeatedly. Woo et al. (2014) revealed that for learners with higher self-efficacy, recognizing the value of studying mathematics had a more positive effect on their feelings and interests regarding mathematics. Among recent studies, Lee et al. (2017) proposed a causal model with elements connected to the affective domain of learning mathematics. The result showed that external or internal motivations were increased when the students realized the value of learning mathematics, and that the two motives increased RII. In the end, this research proposed that PII can affect RII by impacting understanding of the importance and value of learning mathematics. From these studies, it may be concluded that individual interest can be completed when the learners' emotions and attitudes toward the object are positive, and when they recognize the value of learning mathematics.

Through the preceding studies, the relationships between the four sub-elements of mathematical interest were examined. However, there were no empirical studies examining how the situational interest that occurred in class mediates between ESI and individual interest. Also, there were no studies examining how the interest felt while recognizing the value of learning mathematics affects the RII, which can be seen as the final product of individual interest, by mediating situational interest. Therefore, based on the six hypotheses, as shown in **Figure 1**, developmental path model of interest in learning mathematics of paths 1 ~ 6 is established and the mediating effect of CSI and PII will be verified.

By reviewing previous studies, this research examined the relationship between different types of student interest classified into four sub-elements. However, there was not any empirical study analyzing how the situational interest that occurred in the class functions as a mediator between ESI and individual interest. Furthermore, there were not studies examining how a student's recognition of the importance of learning mathematics affect the levels of RII, the final outcome of individual interest, by incorporating the mediating effects of situational interest levels. Therefore, based on the six hypotheses as shown in **Figure 1**, this research suggests a developmental path model measuring interest levels of mathematics with the previously-mentioned hypothetical pathways 1 through 6, and verify the mediating effects of CSI levels and PII levels.

Relationship Between Interest in Learning Mathematics and Academic Achievement in Mathematics

How RII can influence academic achievement in mathematics

Choi and Sang (2019) summarized previous studies on variables that can affect students' levels of academic achievement in mathematics. Although various factors are possible, many studies have proposed that interest in learning mathematics exhibits a significant influence on achievement (Chung et al., 2014; Ju et al., 2011; Lee et al.,

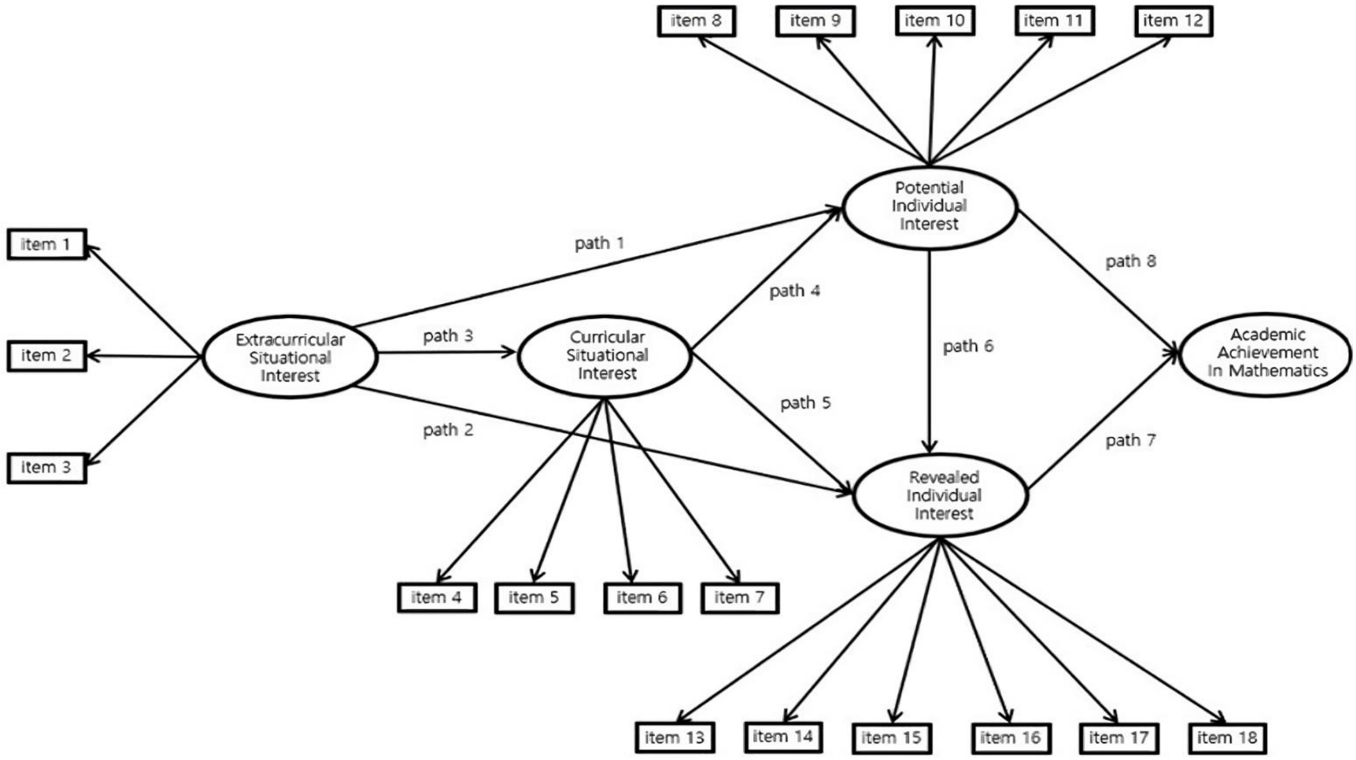

Figure 1. Proposed path model (for item number, refer to it in **Table 7**) (Source: Authors' own elaboration)

Table 5. RII items 2

Kim et al. (2021)	Kim et al. (2014)	Rotgans & Schmidts (2017)
□ Mathematics is enjoyable & stimulating.	□ I enjoy studying mathematics.	□ I look forward to science class because I like science class so much.
□ Mathematics makes me nervous and embarrassed.	□ I wish I did not have to study mathematics.	□ I read a lot of books about science.
□ Mathematics is my least favorite & most dreaded subject.	□ I am bored with mathematics.	
□ Mathematics makes me anxious & disoriented.	□ I learn a lot of interesting things in mathematics classes.	
□ Math is so much fun that I am always absorbed in it.	□ I like mathematics.	

2012). Most previous studies used the testing tools of PISA 2007 and PISA 2011 to analyze students' levels of interest. Questions measuring interest levels in these tests focused on asking whether the students enjoyed learning mathematics with items such as "Is studying mathematics enjoyable?", "Is mathematics boring?", and "Do I like mathematics?" Thus, it may be concluded that these items are identical to items measuring RII, which include emotions such as pleasure and boredom while learning mathematics.

In addition, previous studies found that the variable of interest in learning mathematics is related to the variable of academic achievement in mathematics (Heinze et al., 2005; Kim et al., 2021, 2014; Lew & Hwang, 2019; Oh, 2000; Shin & Park, 2012; Song, 2017; Rotgans & Schmidt, 2017).

Table 5 summarizes the measuring tools used in three studies. The contents of the tools used in most studies analyzing the influence of interest in learning mathematics on academic achievement do not seem to deviate significantly from the contents presented in the table. Therefore, RII can be a positive factor influencing the students' academic achievement in mathematics. Likewise, the influence of interest variables on the levels of academic achievement in mathematics has been studied in various ways along the lines of gender and grade levels. In particular, studies that considered gender found that male students showed more interest in mathematics that female students (Kim & Jeon, 2013; Lee & Song, 2011), and studies by grade levels showed that students became less interested in learning mathematics as their academic careers progressed (Lew & Hwang, 2019; Yoon, 2006). Therefore, after verifying the suggested model, we investigated whether the results of the model may differ according to gender and grade levels.

How PII can influence academic achievement in mathematics

In particular, this study divided individual interest into categories of a) interest related to the recognition of the value of learning mathematics and b) interest related

Table 6. Distribution of participants

Division		Frequency (persons)	Percentage (%)
Gender	Male	733	53.04
	Female	649	46.96
	Total	1,382	100.00
Grade levels	First grade (male/female)	485 (274/211)	35.09 (19.83/15.27)
	Second grade (male/female)	419 (230/89)	30.32 (16.64/13.68)
	Third grade (male/female)	478 (229/249)	34.59 (16.57/18.02)
	Total grade (male/female)	1,382 (733/649)	100.00 (53.04/46.96)

to the emotion about learning mathematics at the moment. Park (2008a) stated that recognition of the value of studying mathematics has a significant effect on academic achievement in mathematics. Kim et al. (2014) found that students with positive attitudes toward mathematics showed higher levels of achievement than students with negative attitudes. However, Jung and Song (2020) revealed that although the recognition of the value of learning mathematics has been frequently investigated in the affective domain, only a few studies have been conducted and they did not even clearly define the relationship between interest and academic achievement in mathematics. Other studies have also reported that the relationship between the recognition of the value of learning mathematics and the level of academic achievement remains unclear (Fisher et al., 2012; Singh et al., 2002). These results suggest that students' subjective levels of interest while recognizing the value of learning mathematics may not directly affect their academic achievement, and an indirectly mediating factor may be expected between these two variables.

Based on previous studies, we constructed a path model showing structural relationships between the four sub-elements of interest in mathematics and academic achievement, as shown in **Figure 1**. The results show that, like the premise that situational interest can be developed into individual interest, ESI and CSI can affect PII and RII as in path 1, path 2, path 4, and path 5. In addition, the paths were modified to analyze the influence of ESI on CSI by adding path 3, and the influence of PII on RII by adding path 6. It may be assumed that the developmental path model of interest in learning mathematics can elucidate the mediating effects on CSI and PII.

Also, the relationship between PII experienced by recognizing the value of learning mathematics and academic achievement in this subject, as shown in path 8, is not clear, so we predicted that there could be a mediating factor between these two variables. Because interest in learning mathematics is one of the variables predicting a positive effect on academic achievement in mathematics, we found that RII always exhibited a significant effect on academic achievement, as shown in path 7. Therefore, as this research analyzed how RII functions between PII and academic achievement as a mediator, the results can serve to clarify the structural relationship between interest in learning mathematics and academic achievement in the subject.

RESEARCH PROCEDURES AND METHODS

Research Participants

Jackson (2001, 2003) suggested the acceptable number of participants for structural equation modeling (SEM) and factor analysis models. He stated that for a sample size *N* and some number of parameters to be estimated *q*, the ideal ratio *N:q* should be 20:1, with 10:1 as the lowest acceptable ratio. Bentler and Chou (1987) claimed that the appropriate ratio between the parameters to be estimated and the number of subjects in the sample could be 10:1 and suggested that the lowest acceptable ratio should at least be 5:1. Kline (2011) also proposed that the typical number of samples for SEM could be 200 as an absolute criterion. Therefore, we decided that the appropriate number of participants in the present work should be approximately 1,440 by following Jackson's (2001, 2003) theory. In this research, we conducted a survey of 1,385 male and female high school students in a metropolitan area. A total of 1,382 subjects were included in the final analysis; three insincere respondents were excluded. The participants comprised 733 male students and 649 female students. In terms of their distribution by grade levels, 485 students were in the first grade, 419 students were in the second grade, and 478 students were in the third grade. As shown in **Table 6**, the participants were roughly evenly distributed according to both gender and grade levels.

Measurement Tool and Data Collection

We used a measuring tool developed by Park et al. (2019). As shown in **Table 7**, the tool includes ESI, CSI, PII, and RII as four sub-elements with 18 items derived from them. Three items were included for each element for ESI, four for CSI, five for PII, and six for RII. Each item was scored on a six-point 'Likert scale' adopted from consideration of Shin's (2000) observation that the central option from odd-numbered scale could be selected by insincere respondents to avoid responding. The options of the scale were "very strongly disagree (one points)", "strongly disagree (two points)", "slightly disagree (three points)", "slightly agree (four points)", "strongly agree (five points)" and "very strongly agree (six points)".

Table 7. Elements and items of situational and individual interest

IN	SE	Items
I1	ESI	I found learning math more interesting when I participated in activities like math clubs, experiential exhibitions, etc.
I2		Due to experience of securing mathematics data from public institutions, I became more interested in learning math.
I3		I am interested in sharing information on mathematics with my friends.
I4	CSI	I enjoy mathematics class at my school.
I5		Mathematics class is not boring, so it goes by quickly this semester.
I6		Mathematics class holds my attention this semester.
I7		I feel excited about mathematics class this semester.
I8	PII	Studying mathematics can help me do what I want to do in the future.
I9		I am studying a great deal to improve my mathematics skills.
I10		I want to study hard to improve my mathematics skills.
I11		I want to have a job related to mathematics.
I12		Learning mathematics is valuable to me.
I13	RII	I like mathematics.
I14		I wish I didn't have to study mathematics. (reverse coding).
I15		I like solving mathematics questions.
I16		I have a positive attitude toward mathematics.
I17		I am passionate about studying mathematics.
I18		I have difficulty learning mathematics.

Note. IN: Item number; I: Item; & SE: Sub-elements

Data Analysis

In this study, we used SEM to analyze the relationships between the four sub-elements of interest in learning mathematics and academic achievement. Because SEM is a statistical model that examines the structural relationships between latent variables (Kim, 2016), we considered SEM to be the most suitable method to analyze the relationships between the elements and the development of interest in learning mathematics. To evaluate the fit of the model, we used χ^2 verification, Tucker-Lewis index (TLI), comprehensive fit index (CFI), and root mean square error of approval (RMSEA). Steiger (1989) has argued that the suitability of fit may be considered appropriate for RMSEA values less than .10. RMSEA values less than .05 indicate very good suitability, while values less than .01 indicate the best-fitting solutions. Standardized root mean square error (SRMR) values less than .08 may be considered to indicate that a model secures an appropriate suitability of fit. In addition, TLI/CFI values of .95 or higher were considered an appropriate fit, and TLI/CFI higher than .90 was considered a good fit (Bentler, 1990). The reliability of factor analysis was analyzed with composite reliability (CR), also known as construct reliability (CR), which measures the internal consistency of an indicator. Also, the reliability can be calculated with average variance extraction (AVE). AVE demarcates the size of variance, which can be explained within a given conceptual framework. In general, if CR is greater than .70 and AVE is greater than .50, the factor analysis could be judged to have secured statistical validation (Fornell & Larcker, 1981).

Prior to applying SEM, we conducted descriptive statistics and correlations of the variables from the 1,382 data-contributing subjects by means of SPSS. In addition, we performed an exploratory factor analysis (EFA) to reconfirm the validity of the test tool using MPLUS program.

To examine how the relationship between interest in learning mathematics and academic achievement in mathematics differed according to gender and grade levels, we conducted a multigroup analysis to verify whether the parameters of each group in the measurement model were identical with those of the other groups. The analysis was performed according to the following four procedures of the multigroup analysis model suggested by Lynam et al. (1993). First, we performed a separate sample analysis that could estimate the parameters of each group individually. Second, we employed a cross-group equality constraint model to verify whether the parameters set in a strict way were the same across the groups. Third, we performed a χ^2 test between the first and second models. If the model-fit with the equivalence constraint was worse than the model-fit without the equivalence constraint, it may be inferred that the path coefficient differed across the groups. Fourth, even though there was no significant difference in the path coefficients between the two models in the third step, it could estimate an equality-unconstrained model that did not impose equivalence constraints between the groups, specifically, for each path. Then, the difference between the equivalent constraint model and the non-equivalent constraint model was tested with χ^2, where a statistically significant difference indicated a difference in the parameters between the groups.

RESULTS

Validity Analysis of the Measuring Tool

As a result of an EFA to analyze the validity of the testing tool, the four sub-elements present the fitness as shown in **Table 8**.

Table 8. Model fit of EFI

χ^2	RMSEA	CFI/TLI	SRMR
429.926 (87)	.073	.965/.938	.023

Table 9. Descriptive statistics of variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	AAM
EII	I1	1.000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	I2	.802	1.000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	I3	.726	.740	1.000		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CSI	I4	.310	.269	.309	1.000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	I5	.305	.277	.284	.575	1.000		-	-	-	-	-	-	-	-	-	-	-	-	-
	I6	.343	.295	.323	.600	.629	1.000	-	-	-	-	-	-	-	-	-	-	-	-	-
	I7	.390	.352	.379	.679	.666	.765	1.000	-	-	-	-	-	-	-	-	-	-	-	-
PII	I8	.386	.331	.381	.404	.401	.440	.467	1.000	-	-	-	-	-	-	-	-	-	-	-
	I9	.286	.241	.315	.473	.485	.502	.532	.498	1.000	-	-	-	-	-	-	-	-	-	-
	I10	.300	.240	.325	.429	.478	.479	.513	.552	.669	1.000	-	-	-	-	-	-	-	-	-
	I11	.435	.398	.408	.415	.392	.425	.473	.666	.439	.424	1.000	-	-	-	-	-	-	-	-
	I12	.412	.375	.443	.537	.511	.547	.615	.679	.589	.614	.657	1.000	-	-	-	-	-	-	-
RII	I13	.377	.346	.428	.593	.478	.506	.565	.516	.584	.504	.559	.648	1.000	-	-	-	-	-	-
	I14	.297	.305	.313	.470	.428	.400	.472	.445	.431	.412	.506	.578	.615	1.000	-	-	-	-	-
	I15	.373	.340	.424	.548	.480	.501	.564	.500	.554	.530	.552	.653	.786	.629	1.000	-	-	-	-
	I16	.388	.364	.421	.599	.531	.553	.594	.533	.601	.572	.543	.693	.791	.660	.782	1.000	-	-	-
	I17	.334	.294	.366	.549	.535	.572	.597	.493	.737	.612	.477	.647	.693	.517	.681	.741	1.000	-	-
	I18	.236	.249	.269	.388	.289	.311	.359	.313	.374	.224	.384	.364	.546	.466	.478	.479	.413	1.000	-
AAM		.191	.158	.233	.292	.259	.325	.327	.297	.488	.319	.275	.348	.470	.274	.416	.405	.470	.356	1.000
Mean		.2973	2.818	3.204	3.558	3.547	3.201	3.176	3.556	3.767	4.101	2.586	3.426	3.582	3.161	3.352	3.577	3.628	2.970	106.608
Variance		.2057	1.906	2.335	1.890	1.750	1.770	1.997	2.662	1.986	2.104	2.231	2.072	2.307	2.427	2.059	2.008	2.089	1.893	411.400
Skewness		.260	.345	.106	-.089	-.242	-.021	.012	-.147	-.342	-.617	.629	-.131	-.239	.271	-.058	-.238	-.305	.339	-.066
Kurtosis		-.727	-.642	-.936	-.666	-.416	-.605	-.760	-1.09	-.563	-.304	-.565	-.782	-.973	-.918	-.817	-.693	-.712	-.520	-.666

Note. I: Item

Table 10. Goodness of fit of the SEM

χ^2	RMSEA	CFI/TLI	SRMR
1,525.074 (145)	.083	.927/.914	.045

Table 11. Results & reliability of CFA

IN	SE	NSPC	SPC	Reliability (CR)	Average (AVE)
I1	ESI	1.000	.892	.904	.759
I2		.963	.893		
I3		.988	.827		
I4	CSI	1.000	.759	.885	.659
I5		.951	.750		
I6		1.058	.830		
I7		1.219	.900		
I8	PII	1.000	.881	.911	.636
I9		.827	.710		
I10		.930	.867		
I11		.954	.901		
I12		.876	.811		
I13	RII	.575	.559	.874	.582
I14		1.000	.754		
I15		.833	.728		
I16		.858	.723		
I17		.883	.727		
I18		1.021	.872		

Note. IN: Item number; I: Item; SE: Sub-elements; NSPC: Non-standardization path coefficient; SPC: Standardization path coefficient

Path Analysis for Overall Group

Before presenting the results of SEM analysis, we summarize the descriptive statistics of the variables in **Table 9**.

Next, the fit of SEM is presented in **Table 10**. This table shows that RMSEA value is slightly high, but the other indices generally indicate that the model exhibits a good fit.

Table 11 shows the results of a confirmatory factor analysis (CFA), and CR and AVE as reliability indicators. This analysis shows that the factors were properly grouped because CR was greater than .70 and AVE was greater than .05 according to the criteria suggested by Fornell and Larcker (1981).

Table 12 and **Figure 2** show the results of analyzing direct and mediating effects of SEM to confirm the relationships between interest in learning mathematics and levels of academic achievement in mathematics.

Table 12 shows that the direct effect sizes of most paths were statistically significant at the $p<.001$ level, except for path 2 and path 8. ESI (.454) affected CSI and this relationship exhibited an explanatory power of about 20.7%. Also, 62.9% can be explained by the

Table 12. SEM model

Path number	Path	Standard error	Direct effect	Indirect effect	Total effect
Path 1	ESI→PII	.024	.219***	-	.523***
	ESI→CSI→PII	-	-	.304**	
Path 2	ESI→RII	.021	.027	-	.484***
	ESI→ CSI→PII	-	-	.104***	
	ESI→ PII→RII	-	-	.148***	
	ESI→CSI→PII→RII	-	-	.205***	
Path 3	ESI→CSI	.024	.454***	-	-
Path 4	CSI→PII	.020	.669***	-	-
Path 5	CSI→RII	.031	.228***	-	.679***
	CSI→ PII→RII	-	-	.451***	
Path 6	PII→RII	.031	.674***	-	-
Path 7	RII→AAM	.060	.462***	-	-
Path 8	PII→AAM	.063	.037	-	.348***
	PII→RII→AAM	-	-	.311***	

Note. *p<.05; **p<.01; & ***p<.001

influence of ESI (.219) and CSI (.669). In addition, CSI (.228) and PII (.647) exhibited a positive effect on RII with an explanation of approximately 76.9%. Finally, it could be explained by approximately 24.4% that academic achievement in mathematics was affected by RII (.462). Next, we analyzed the mediating effect of path 1, path 2, path 5, and path 8. The indirect and the direct effects were statistically significant in path 1 and path 5. However, the direct effect sizes of path 2 and path 8 were .027 and .037, respectively, which were not statistically significant, but indirect effect sizes were .457 and .311 and exhibited a significant mediating effect at the p<.001 level. Therefore, the total effects of path 2 and path 8 were statistically significant.

Analysis of Differences According to Gender and Grade Levels

To confirm the relationship between interest in learning mathematics and academic achievement with gender and grade levels, we analyzed the multigroup analysis model procedure suggested by Lynam et al. (1993) based on the final model shown in **Figure 2**. Path

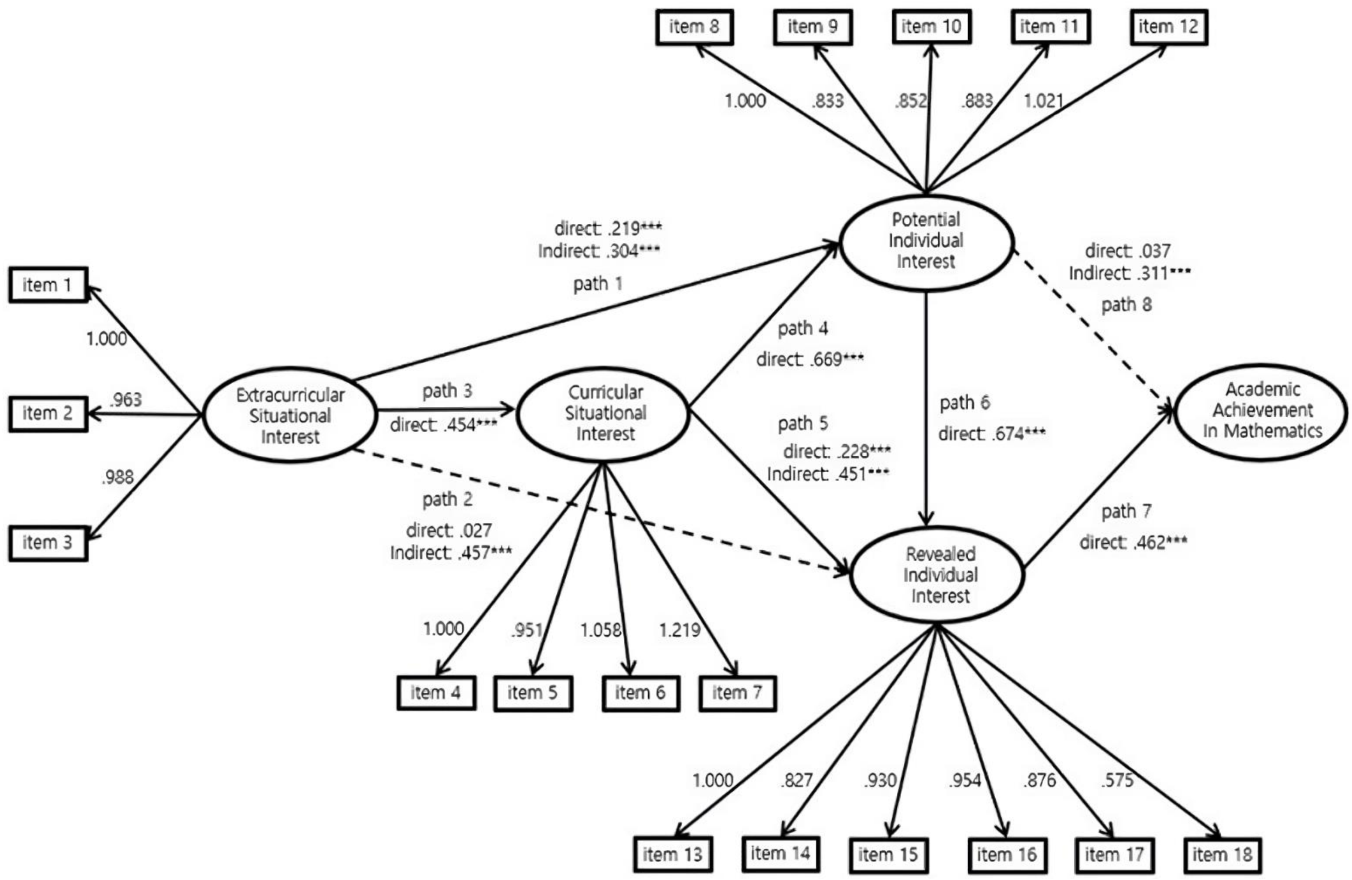

Figure 2. Path model of relationships between interest in learning mathematics & academic achievement in mathematics (*p<.05; **p<.01; & ***p<.001) (Source: Authors' own elaboration)

Table 13. Multigroup analysis according to gender

Path number	Direct effect	χ^2 of equivalent ratio constraint model	χ^2 difference	Individual sample analysis***	
				Male	Female
Path 1	ESI→PII	2110.711 (325)	45.913 (p=1.236)	.226***	.226***
Path 3	ESI→CSI	2019. 387 (325)	137.237 (p=1.070)	.433***	.433***
Path 4	CSI→PII	2156.369 (325)	.255 (p=.614)	.743***	.743***
Path 5	CSI→RII	2156.624 (325)	0.000 (p=1)	.294***	.294***
Path 6	PII→RII	2155.139 (325)	1.485 (p=.223)	.725***	.725***
Path 7	**RII→AAM**	**2143.760 (325)**	**12.864 (p<.001)*** **	**9.310*** **	**5.027*** **

Note. *p<.05; **p<.01; & ***p<.001

Table 14. Multigroup analysis according to grade levels (first grade/upper grades)

Path number	Direct effect	χ^2 of equivalent ratio constraint model	χ^2 difference	Individual sample analysis***	
				First grade	Upper grade
Path 1	ESI→PII	2010.897 (325)	77.959 (p=1.052)	.216***	.216***
Path 3	ESI→CSI	2067.410 (325)	21.446 (p=3.639)	.421***	.421***
Path 4	CSI→PII	2067.375 (325)	21.480 (p=3.574)	.790***	.790***
Path 5	CSI→RII	2088.612 (325)	.244 (p=.621)	.285***	.285***
Path 6	**PII→RII**	**2083.958 (325)**	**4.898 (p=.027)***	**.631*** **	**.753*** **
Path 7	**RII→AAM**	**2076.346 (325)**	**12.51 (p<.000) *** **	**9.336*** **	**5.628*** **

Note. *p<.05; **p<.01; & ***p<.001

2 and path 8 were not statistically significant and were therefore excluded from the analysis.

Analysis of sex differences by gender

The result of verifying the χ^2 difference between the model with equivalent constraints and the model without equivalent constraints for all the paths showed that the differences were not statistically significant. The results of testing for differences between the groups along the six pathways are shown in **Table 13**. The analysis shows that there was a significant difference between genders in the direct pathway of path 7.

Analysis of differences according to grade level

The result of verifying the χ^2 difference between the model with equivalent constraints and the model without equivalent constraints for all the routes shows that the differences were not statistically significant. The results of testing the differences between the groups for the six pathways are shown in **Table 14**. There was a significant difference between the first and upper grades in the direct pathways of path 6 and path 7.

DISCUSSION

Developmental Path of Interest in Learning Mathematics and Relationships Between Levels of Interest and Levels of Academic Achievement in Mathematics

Developmental paths of different levels of interest in learning mathematics

Based on the results of SEM analysis with path 1 to path 6, we derived the following implications for the development of interest in learning mathematics.

Although ESI can be directly developed into PII, it can be more highly developed when CSI is also included as mediation. In other words, this result can be interpreted to indicate that when students experience ESI from creative-practicum activities outside of mathematics classes, it has a positive effect on the levels of CSI inside mathematics classes and finally leads to potential recognition of the importance and value of learning mathematics. As shown in many previous studies, career-related activities and club activities conducted outside of mathematics classes play a positive role for students in understanding the importance of learning mathematics (Kim & Kim, 2014; Kim et al., 2011). In addition, this study found that not only the teaching and learning methods and activities, but also various factors in mathematics classes play an important role for students in realizing the value of learning mathematics by participating in extracurricular activities (Na & Son, 2016; Park & Han, 2018)

The results of this work show that CSI can also be directly developed into RII but can be developed more highly through mediation with PII. When students feel CSI generated by various teaching and learning methods and activities in mathematics classes, they can recognize the value and necessity of learning mathematics and develop an individual interest in the subject itself. These results are consistent with the findings of previous studies indicating that students understand the use of mathematics in real life and recognize the practical aspects of learning mathematics through various methods and activities such as project-based learning, inquiry-based learning, and other teaching and learning methods suggested by the 2015 revised mathematics curriculum (Cho & Kim, 2013; Do & Choi, 2011; Na & Son, 2016; Park & Han, 2018, 2021). The results of the present work are similar to those of the casual model measuring affective domains suggested by Lee et al.

(2017), indicating that motivation can occur when students recognize the value of learning mathematics, and this recognition affects their RII in the final tally.

Finally, this study found that ESI can become RII by mediating CSI and PII. In particular, although there are various studies on the influence of ESI on RII (Kim & Kim, 2014; Seo, 2012), the results of this study showed that ESI does not directly affect RII. The interest generated by extracurricular activities could be difficult to develop into interest related to the potentiality and possibility of learning mathematics, and this interest did not exhibit any significant effect on individual interest, which should be essentially pursued through creative-practicum activities currently provided in schools (Marsh, 1992; Marsh & Kleitman, 2002). However, because the mediating effect of CSI and PII is statistically significant, interests induced outside of the classroom can be maintained when the students recognize the importance and value of learning mathematics as well as participating in classroom activities and various methods set up by the teacher. Ultimately, students can develop RII that represents their current feelings and attitudes toward learning mathematics.

The developmental path model identified for different levels of interest in learning mathematics in this study can support the premise that CSI generally develops into individual interest (Hidi, 1990; Hidi & Baird, 1986; Kim, 1996; Krapp, 2000; Renninger et al., 1992; Schiefele, 1991; Wiśniewska, 2013). This work also enables to investigate the paths for students to develop interest in mathematics beyond only the distinction between situational interest and individual interest, as suggested by many researchers (Hidi & Renninger, 2006; Krapp, 2002; Linnenbrink-Garcia et al., 2010). This developmental path model suggests the following implications for mathematics education.

The importance of extracurricular activities could be reviewed because ESI can directly affect the development of PII. Previous studies have mostly focused on the effects of career-related activities and club activities as elements of larger creative-practicum programs that can help the students recognize the importance and value of learning the given subjects (Kim & Kim, 2014; Seon et al., 2007). However, in addition to this, providing students with programs based on discretionary activities and volunteering activities along with other types of creative-practicum activities is also necessary so that the students can recognize the value and importance of learning mathematics. Considering that the mediating effect of CSI is significant, teaching and learning methods and activities in mathematics classes should connect to creative-practicum activities for students to help them recognize the importance and value of learning mathematics. As in the research of Kim and Kim (2014) that found that operating a science club as a creative-practicum activity improved students' PII in science classes, mathematics clubs and extracurricular activities can also raise students' awareness of the value of learning mathematics by connecting classroom lessons with creative-practicum activities.

Because CSI can directly affect not only the development of PII but also the improvement of RII, the importance of CSI must be considered, as it can affect students' individual interest. This result indicates that additional follow-up studies on the factors of situational interest related to the teaching and learning methods and activities are needed, given that it is among the main factors in mathematics classes. In addition, Hidi and Renninger (2006) stated that different types of interests share common characteristics for each level and overlapped with each other, so it will also be necessary to check whether the factors needed for development into individual interests should be included in the creation of teaching and learning methods.

Finally, we found that ESI does not directly affect the development of RII, but it can develop into RII through mediation with CSI and PII. In the end, however, it is difficult for students to achieve individual interest only with activities outside the classes. However, if the students recognize the importance of learning mathematics and connect both in-class and out-of-class elements, they can more reliably develop genuine individual interest in mathematics. The main body organizing and operating creative-practicum activities is the school, but students can also autonomously select, organize, and perform these activities. Therefore, while extracurricular activities by themselves may not develop students' interest, the preponderance of the relevant literature shows that teachers should design classes by considering most students' interest in affective areas (Choi & Han, 2013). Therefore, we recommend more research into CSI based on the findings of the present work, given that it seems to be significant in mathematics classes.

On the relationship between the interest in learning mathematics and academic achievement in mathematics

Based on the results of the SEM analysis of paths 6 to 8, the following implications were derived for the relationships between the levels of interest in learning mathematics and levels of academic achievement in mathematics.

Although PII does not directly affect academic achievement in mathematics, it was found that its mediation with RII exhibited a positive effect on the levels of achievement. In other words, recognizing the importance and value of learning mathematics alone does not seem to affect the students' levels of achievement in the subject, but understanding the potentialities of learning mathematics can improve their feelings, attitudes, and openness to challenges in mathematics, ultimately, influencing their achievements positively. This is consistent with the results showing that interest variables have a positive effect on academic achievement in mathematics through cognitive development (Choi & Sang, 2019), but our results on the relationship between the perceived valued of learning mathematics and academic achievement are not aligned with those of previous studies (Kim et al., 2014; Park, 2008b). This may be attributed to the fact that the relationship between the perception of value of learning mathematics and academic achievement is not properly matched (Fisher et al., 2012; Jung & Song, 2020; Singh et al., 2002). However, the theory that recognition of the value of learning mathematics and improving the amount of openness to challenges in mathematics having a positive effect on students' achievement is presented in many studies (Heinze et al., 2005; Kim et al., 2021; Krapp & Prenzel, 2011; Lew & Hwang, 2019; Rotgans & Schmidt, 2017).

Improvement in levels of academic achievement in mathematics caused by the interaction of PII and RII demands the students' stimulation and challenges in mathematics itself to realize possibilities rather than the potentialities and possibilities of learning mathematics, which students can only feel. In this context, students may develop individual interest in mathematics, but providing an environment encouraging students' CSI is important, especially for many students who do not feel any interest in mathematics, so that their CSI can develop into individual interest.

Differences Between Levels of Interest in Learning Mathematics and Academic Achievement in Mathematics Along Lines of Gender and Grade Levels

Based on the results of the analysis of the relationship between interest in learning mathematics and the academic achievement in mathematics, we derived the following implications.

Although there was no difference in the CSI levels along the lines of gender or grade levels, we found that there was a significant difference in the effect of RII–the goal of interest development in learning mathematics–on academic achievement. Differences along the lines of gender and grade levels show that students' individual internal emotional states, including an openness to challenges in mathematics, can influence their academic achievement. This finding is consistent with the results of other studies finding that interest levels adjusted for gender and grade levels showed an impact on the levels of academic achievement in mathematics (Hwang & Lew, 2018; Kim, 2013; Lee & Song, 2011). Similarly, Park et al. (2019) found that, in particular, male students exhibited higher RII than female students. RII includes not only the students' attitudes toward learning mathematics, such as feelings of pleasure or boredom, but also their emotional states, such as openness to challenges in learning mathematics in the future. Simplifying this slightly, because male students appear to exhibit more openness to challenges than females (Ju et al., 2011), it may be assumed that there is a difference in their levels of academic achievement resulting from differing levels of cognitive development arising from gender differences. It can be inferred that the differences in the mindsets of first grade students and upper grade students arise because the upper grade students need to prepare for mathematics required for university entrance examinations, whereas first grade students have no such requirement or face much less pressure.

Next, the effects of PII on RII differed with the grade levels. That is, it may be observed that the effect of interest felt while recognizing the value of learning mathematics on academic achievement in mathematics differed substantially between first graders and upper grade students. Like the study conducted by Park et al. (2019), we found a difference in the relationship with academic achievement in the present work, given that the first graders showed higher PII than the second and third graders.

We conclude that differences in general characteristics can be attributed to individual levels of interest–a factor affecting academic achievement in mathematics–which is the result of variations in cognitive development. Individual interest can be an inherent individual tendency related to the belief that one can perform well in mathematics, but it may also result from the development of students' CSI, which schools can encourage (Woo, 2012). Therefore, from this point of view, educators and administrators must create an environment that drives students to experience CSI both in and out of their mathematics classrooms.

CONCLUSIONS & RECOMMENDATIONS

This study examined how students' interest in mathematics learning develops. Based on the findings from the current study, it should be noted that interest in mathematics learning needs to be highlighted in the public and private education. As Woo (2012) pointed out, in this study, it was emphasized the importance of stimulating situational interest in class of students who lack motivation for subject learning. Next, further research suggestions are proposed for the development of interest in learning mathematics and limitations are presented in this study. Lawhorn (2008) mentioned that the decision to participate in extracurricular activities is controlled by learners, reflecting individual student interest and its value in learning. Also, Rotgans and Schmidt's (2017) study on the effect of individual interest on situational interest in science subjects found that the effect of individual interest on situational interest disappears from the moment that students enter a given problem situation, but that providing students with a problem with a topic embedded individual interest causes situational interest. Even though the current stud is based on Hidi and Renninger's (2006) study that situational interest develops into individual interest, but the results of Rotgans and Schmidt (2017) suggested a new development process and that some individual interest in all subjects could affect situational interest. Therefore, we propose a follow-up study on the new developmental process in which individual interest is cycled into situational interest in mathematics subjects.

Since December 2019, COVID-19 pandemic has changed the overall composition of societal relations into non-face-to-face situations. Therefore, in the school education system, normal school schedule operation and face-to-face classes were not possible for a while, non-face-to-face online classes being the mainstream. During this study was implemented, due to the outbreak of COVID-19, it was not possible to have a face-to-face class meeting with the students, so the process of selecting a small number of target students and face-to-face sessions had to be eliminated. Therefore, in this study, only the results of measuring situational interest and individual interest in mathematics learning at the same time are presented. It follows that there will be a need for the future research to examine changes in situational interest and individual interest over time.

Author contributions: All authors have sufficiently contributed to the study and agreed with the results and conclusions.

Funding: This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2021S1A5C2A03089476).

Acknowledgements: The authors would like to thank Dr. Moonbok Lee and Dr. Bokyung Cho for their help on this paper.

Ethical statement: Authors stated that the study was approved by Sungkyunkwan University IRB in October/14th/2019, and the approval number is 2019-10-013-002.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

Bae, S. H. (2018). Hands-on activities based on GIS and problem-based learning (PBL) in secondary school geography lesson. *Journal of Photo Geography (Sajin Chiri), 28*(3), 101-114. https://doi.org/10.35149/jakpg.2018.28.3.008

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*(2), 238-246. https://doi.org/10.1037/0033-2909.107.2.238

Bentler, P. M., & Chou, C.-P. (1987). Practical issues in structural modeling. *Sociological Methods & Research, 16*(1), 78-117. https://doi.org/10.1177/0049124187016001004

Bloom, B. S. (1985). The nature of the study and why it was done. In B. Bloom (Ed.), *Developing talent in young people* (pp. 3-18). Ballantine.

Cho, H. J., & Kim, D. S. (2013). The relationship between cooperation learning in mathematics and their attitudes towards mathematics. *Korean Comparative Education Society, 23*(4), 131-154.

Choe, S. H., & Lee, D. H. (2005). An analysis on the implementation and the methods of development of the 7th differentiated mathematics curriculum. *The Korea Society of Mathematical Education, The Mathematical Education, 44*(3), 325-336.

Choe, S. H., Park, S. W., & Hwang, H. J. (2014). Analysis of the current situation of affective characteristics of Korean students based on the results of PISA and TIMSS. *Journal of the Korean School Mathematics Society, 17*(1), 23-43.

Choi, J. S., & Sang, K. A. (2019). The effects of educational context variables on achievement and interest in mathematics in high and low achieving students. *Journal of the Korean School Mathematics Society, 22*(2), 163-183. https://doi.org/10.30807/ksms.2019.22.2.004

Choi, K. H., & Han, H. S. (2013). A study on the effects of the reciprocal peer tutoring in high school students' affective characteristics of mathematics. *The Korea Society of Mathematical Education, The Mathematical Education, 52*(3), 423-442. https://doi.org/10.7468/mathedu.2013.52.3.423

Choi, Y. H., & Kim, Y. J. (2020). Exploring students' perceptions of the educational effects of out-of-school science center. *Journal of Education Science, 22*(4), 23-41. https://doi.org/10.15564/jeju.2020.11.22.4.23

Chung, J. Y., Lee, H. S., & Kim, S. J. (2014). A hierarchical analysis of the factors influencing on student achievement- Using the teacher and student factors of TIMSS 2011. *The Journal of Korean Teacher Education, 31*(2), 53-75. https://doi.org/10.24211/tjkte.2014.31.2.53

Do, E. H., & Choi, S. W. (2011). The development of problems for mathematical modeling activities and its implementation. *Educational Research Institute Kyung Nam University, 21*, 133-152.

Fisher, P. H., Dobbs-Oates, J., Doctoroff, G. L., & Arnold, D. H. (2012). Early math interest and the development of math skills. *Journal of Educational Psychology, 104*(3), 673-681. https://doi.org/10.1037/a0027756

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39-50. https://doi.org/10.2307/3151312

Heinze, A., Reiss, K., & Franziska, R. (2005). Mathematics achievement and interest in mathematics from a differential perspective. *ZDM Mathematics Education, 37*(3), 212-220. https://doi.org/10.1007/s11858-005-0011-7

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research, 60*(4), 549-571. https://doi.org/10.3102/00346543060004549

Hidi, S., & Baird, W. (1986). Interestingness–A neglected variable in discourse processing. *Cognitive Science, 10*, 179-194. https://doi.org/10.1207/s15516709cog1002_3

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111-127. https://doi.org/10.1207/s15326985ep4102_4

Hwang, S. W., & Lew, K. H. (2018). Relationship between mathematics anxiety and mathematical achievement of middle school students according to gender and grade. *The Korea Society of Mathematical Education, Communications of Mathematical Education, 32*(3), 175-189. https://doi.org/10.7468/jksmee.2018.32.2.175

Jackson, D. L. (2001). Sample size and number of parameter estimates in maximum likelihood confirmatory factor analysis: A Monte Carlo investigation. *Structural Equation Modeling: A Multidisciplinary Journal, 8*, 205-223. https://doi.org/10.1207/S15328007SEM0802_3

Jackson, D. L. (2003). Revisiting sample size and the number of parameter estimates: Some support for the N:q hypothesis. *Structural Equation Modeling: A Multidisciplinary Journal, 10*, 128-141. https://doi.org/10.1207/S15328007SEM1001_6

Ju, Y. J., Lee, C. H., & Kim, S. H. (2011). A comparison study between male and female students on academic self-efficacy, interest, external motivation, and mathematics achievement of high school students. *Journal of Research in Curriculum & Instruction, 15*(4), 1021-1043. https://doi.org/10.24231/rici.2011.15.4.1021

Jung, H. S., & Song, H. N. (2020). Detecting types for the influence of mathematics interest and mathematical perception on mathematics achievement in middle school students: Using REBUS-PLS. *Journal of Korea Society Educational Studies in Mathematics, School Mathematics, 22*(4), 853-868. https://doi.org/10.29275/sm.2020.12.22.4.853

Kim, J. C., Hwang, M. H., & Kim, A. Y. (2011). The mediating effects of positive self-observation and intrinsic work value between experiential activities and career maturity . *The Journal of Career Education Research, 24*(1), 1-23. https://doi.org/10.32341/JCER.2022.3.35.1.1

Kim, J. E., & Jeon, I. H. (2013). Elementary school teacher's cognition on pre-taught students. *Journal of Elementary Mathematics Education in Korea, 17*(2), 371-394. https://doi.org/10.7468/jksmed.2013.17.3.181

Kim, J. H., & Kim, J. N. (2014). The changes of attitude related to science of students in the high school science club through the creative-experience activity of science field. *Journal of Science Education, 38*(3), 471-489. https://doi.org/10.21796/jse.2014.38.3.471

Kim, S. H. (2018). Many-sided analysis on Korean student's affective characteristics in mathematical learning. *Journal of Korea Society Educational Studies in Mathematics, School Mathematics, 15*(1), 61-75.

Kim, S. I. (1996). The role of interest in text comprehension. *Korean Journal of Experimental and Cognitive Psychology, 8*(2), 273-301.

Kim, S. J., Kim, K. H., & Park, J. H. (2014). The effect of mathematics achievement on changes in mathematics interest and values for middle school students. *Journal of Research in Curriculum & Instruction, 18*(3), 683-701. https://doi.org/10.24231/rici.2014.18.3.683

Kim, S. T., Kang, H. M., & Park, Y. J. (2021). An effects of smart learning math class on academic achievement, mathematical interest, and attitude. *The Journal of the Convergence on Culture Technology, 7*(2), 217-226. https://doi.org/10.17703/JCCT.2021.7.2.217

Kim, S. Y. (2016). *Fundamentals and extensions of structural equation modeling: With MPLUS examples*. Hakjisa.

Kline, R. B. (2011). *Principles and practice of structural equation modeling*. The Guilford Press.

Krapp, A. (2000). Interest and human development during adolescence: An educational-psychological approach. In J. Heckhausen (Ed.), *Motivational psychology of human development* (pp. 109-128). Elsevier. https://doi.org/10.1016/S0166-4115(00)80008-4

Krapp, A. (2002). An educational-psychological theory of interest and its relation to self-determination theory. In E. Deci, & R. Ryah (Eds.), *The handbook of self-determination research* (pp. 405-427). University of Rochester Press.

Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods and findings. *International Journal of Science Education, 33*(1), 27-50. https://doi.org/10.1080/09500693.2010.518645

Lawhorn, B. (2008). Extracurricular activities. *Occupational Outlook Quarterly, 9*, 16-21.

Lee, B. J., & Song, M. Y. (2011). Gender differences in mathematics-related attitudes in national assessment of educational achievement. *Journal of the Korean School Mathematics Society, 14*(1), 65-84.

Lee, H. C., Kim, H. W., Baeck, S. G., Ko, H. K., & Yi, H. S. (2017). A causal model analysis of non-cognitive characteristics of mathematics learning. *The Korea Society of Mathematical Education, Communications of Mathematical Education, 31*(2), 187-202. https://doi.org/10.7468/jksmee.2017.31.2.187

Lee, H. J., Park, C. G., & Huh, N. (2012). Effect of contextual variables on mathematics achievement-Based on analysis of TIMSS 2007 using path analysis. *Journal of the Korean School Mathematics Society, 15*(3), 585-603. https://doi.org/10.4134/JKMS.2012.49.3.585

Lee, R. (2019). The meaning of the extra-curriculum-activities in secondary schools in Korea: Based on metaphor analysis of students in teaching class. *Education Research institute, Journal of Education & Culture, 25*(2), 549-573.

Lew, K. H., & Hwang, S. W. (2019). A study on the correlation between mathematics anxiety and mathematics achievement in high school students. *The Korea Society of Mathematical Education, The Mathematical Education, 58*(3), 337-346. https://doi.org/10.7468/mathedu.2019.58.3.337

Linnenbrink-Garcia, L., Durik, A. M., Conley, A. M., Barron, K. E., Tauer, J. M., Karabenick, S. A., & Harackiewicz, J. M. (2010). Measuring situational interest in academic domains. *Educational and Psychological Measurement, 70*, 647-671. https://doi.org/10.1177/0013164409355699

Luthar, S. S., & Sexton, C. (2004). The high price of affluence. In R. V. Kail (Ed.), *Advances in child development* (pp. 126-162).Academic Press. https://doi.org/10.1016/S0065-2407(04)80006-5

Lynam, D. R., Moffitt, T., & Stouthamer-Loeber, M. (1993). Explaining the relation between IQ and delinquency: Class, race, test motivation, or self-control. *Journal of Abnormal Psychology, 102*(2), 187-196. https://doi.org/10.1037/0021-843X.102.2.187

Mahoney, J. L., Harris, A. L., & Eccles, J. S. (2006). Organized activity participation, positive youth development, and the over-scheduling hypothesis. *Social Policy Report, 20*(4), 1-32. https://doi.org/10.1002/j.2379-3988.2006.tb00049.x

Marsh, H. W. (1992). Extracurricular activities: Beneficial extension of the traditional curriculum or subversion of academic goals? *Journal of Educational Psychology, 84*, 553-562. https://doi.org/10.1037/0022-0663.84.4.553

Marsh, H. W., & Kleitman, S. (2002). Extracurricular school activities: The good, the bad, and the nonlinear. *Harvard Educational Review, 72(4)*, 464-514. https://doi.org/10.17763/haer.72.4.051388703v7v7736

Mussen, P. H., Conger, J. J., & Kagan, J. (1969). *Child development and personality*. Haraper & Row.

Na, K. Y., & Son, H. C. (2016). Effect of reading in mathematics classroom on mathematical affective characteristics of middle school students. *Journal of the Korean School Mathematics Society, 19*(1), 83-102.

Oh, S. C. (2000). The consequences of development and application of interest induced learning material on mathematics scholastic achievement–Focused on vocational high school. *Journal of the Korean School Mathematics Society, 3*(2), 111-122.

Park, C. (2008a). Effect of educational contextual variables on mathematics achievement of the different ability groups in Korea. *Journal of Educational Evaluation, 21*(3), 23-41.

Park, H. Y., & Rim. H. M. (2014). Analyzing features of collaborative problem solving competencies in PISA and ATC21S: Implications for instruction and assessment in Korea. *Journal of Learner-Centered Curriculum and Instruction, 9*, 439-462.

Park, J. E., & Han, H. S. (2019). The impact of small group project-based assessment on mathematics learning of 7th grade students. *Journal of Learner-Centered Curriculum and Instruction, 19*(18), 627-652. https://doi.org/10.22251/jlcci.2019.19.18.627

Park, J. H., & Han, S. Y. (2021). Exploring the factors of situational interest in learning mathematics. *Journal of Korean Society Mathematics Education, The Mathematics Education, 60*(4), 555-580. https://doi.org/10.7468/mathedu.2021.60.4.555

Park, J. H., Kang, Y. K., & Han, S. Y. (2019). The development and application of the instrument for measuring Korean high school students' interests in mathematics learning. *Journal of Korea Society Educational Studies in Mathematics, School Mathematics, 21*(2), 319-346. https://doi.org/10.29275/sm.2019.06.21.2.319

Park, J. I. (2012). *A study on math club programs in creative experiential activities–Focusing on developing programs* [Master's thesis, University of Incheon].

Park, M. J. (2008b). Students' perceptions of good teaching in higher education–An essay-review of college students. *The Journal of Humanities Studies, 35*(3), 229-253.

Park, Y. H. (2015). Increasing learning attitude and interests for students through various quest activities. *The Journal of Future Education, 5*(2), 27-42.

Renninger, K. A., Hidi, S., & Krapp, A. (1992). *The role of interest in learning and development*. Erlbaum.

Rotgans, J. I., & Schmidt, H. G. (2017). The role of interest in learning: Knowledge acquisition at the intersection of situational and individual interest. In P. A. O'Keefe, & J. M. Harackiewicz (Eds.), *The science of interest* (pp. 69-93). Springer. https://doi.org/10.1007/978-3-319-55509-6_4

Schiefele, U. (1991). Interest, learning, and motivation. *Educational Psychologist, 26*, 29-323. https://doi.org/10.1080/00461520.1991.9653136

Schraw, G., & Lehman, S. (2001). Situational interest: A review of the literature and directions for future research. *Educational Psychology Review, 13*, 23-52. https://doi.org/10.1023/A:1009004801455

Seo, I. H. (2012). *A study on high school mathematics program for developing creativity through experience activities* [Master's thesis, Korea National University of Education].

Seon, H. Y., Hwang, M. H., & Kim, Y. B. (2007). The relation of parents' support and adolescents' intrinsic value pursuing. *The Korea Journal of Counseling, 8*(2), 549-563. https://doi.org/10.15703/kjc.8.2.200706.549

Shin, D. (2000). *Curriculum and assessment*. Kyoyookbook. https://doi.org/10.7468/jksmee.2012.26.2.177

Shin, I. S., & Park, K. M. (2012). An analysis of changing interests in mathematics and strategic thinking reflected in small group drawing activities using graphs and inequations: With GrafEq software. *Journal of Korean Society Mathematics Education, Communications of Mathematical Education, 26*(2), 177-203.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *Journal of Educational Research, 95*, 323-332. https://doi.org/10.1080/00220670209596607

Song, J. B. (2017). Effects of learning through scratch-based game programming on students' interest in and perceived value of mathematics curriculum. *Journal of The Korean Association of Information Education, 21*(2), 199-208. https://doi.org/10.14352/jkaie.21.2.199

Steiger, J. H. (1989). EzPATH: *Casual modeling*. SYSTAT.

Wiśniewska, D. (2013). Interest and interest-enhancing strategies of adolescent EFL learners. *ELT Journal, 67*(2), 210-219. https://doi.org/10.1093/elt/ccs079

Woo, Y. K. (2012). The current state and future direction of interest research in academic setting. *The Korean Journal of Educational Psychology, 26*(4), 1179-1199.

Woo, Y. K., Kim, S. I., & Bong, M. M. (2014). Interaction effect between temporal proximity of utility value and self-efficacy on interest. *The Korean Journal of Educational Psychology, 28*(1), 1-21. https://doi.org/10.17286/KJEP.2020.34.1.01

Yoon, N. E. (2006). *An investigation study on characteristics of affective domain of secondary school students about mathematics* [Master's thesis, Ewha Womans University].