과학교육연구지, 43권 1호, pp. 1-16 (2019.4)   Jour. Sci. Edu, Vol. 43, No. 1, 1-16 (2019.4)

An Exploratory Study of Middle School Students' Motivation in Science: Comparing a STEM Education Program in Korea and the USA

Hyonyong Lee · Max L. Longhurst[1] · Michael K. Freeman[1] · Hyundong Lee[2]*
Kyungpook National University · [1]Utah State University · [2]Daegu National University of Education

Abstract : This exploratory study is aimed at exploring the validity of the Science Motivation Questionnaire (SMQ) developed for university students, to measure the science motivation of middle school students and analyze the differences on gender and country factors of SMQ. A total of 371 students participated in this study: 171 middle school students from the USA and 200 secondary students from Korea. All participants were enrolled in the STEM program and activities in Utah, USA (for US students) and at a Korean university institute for gifted and talented students (for Korean students). In this study, exploratory and confirmatory factor analyses and latent mean analysis were used to analyze the gender and country differences. The results indicated that the 25 items of SMQ scale were theoretically meaningful and valid for middle school students. The latent mean difference by gender indicated that male students have higher intrinsic motivation, career motivation, grade motivation, and self-determination than female students. Moreover, a significant difference exists in these factors between the two countries. Further findings reveal that Korean students scored higher than US students in terms of the aforementioned factors. This study will provide significant insights in and contribution to science motivation issues in STEM education and the development of design-based engineering programs.

keywords : Science Motivation Questionnaire, international comparison, motivation in science, STEM, MESA program

Ⅰ. Introduction

Recently, most OECD countries emphasized science, technology, engineering, and mathematics (STEM) education because of the future needs in these fields. Succeeding in K-12 STEM education has provided more opportunities for students in higher education and in the workplace (Campbell *et al.*, 2012; Kuenzi, 2008; Lips & McNeill, 2009; OECD, 2007, 2014; Sanders, 2009; Williams, 2011). Therefore, improving teaching and learning in STEM education should remain a priority for researchers, educators, and policymakers. The professional communities have strongly supported the integrative approaches to improve STEM education (AAAS, 2001,

---

*Corresponding author : Hyundong Lee (leehd@dnue.ac.kr)

**This Research was supported by Kyungpook National University Research Fund(연구년 교수 연구비), 2016.
***2019년 02월 25일 접수, 2019년 04월 01일 수정원고 접수, 2019년 04월 01일 채택
http://dx.doi.org/10.21796/jse.2019.43.1.1

2007; ITEA, 2003, 2005; NTCM, 2000; NAE, 2004, 2005; NRC, 2012, 2013). As an example, the Next Generation Science Standards in the USA has focused on the connection between science and technology/engineering and integration through disciplinary core ideas, cross-cutting concepts, and practice.

Korea has been facing the same challenges to improve its STEM education, in particular, the effective aspects of learning science and mathematics (Kwak & Ryu, 2016; MOE, 2016; Park & Shin, 2012). Recently, according to the Program for International Student Assessment (PISA), Korean students' interests, motivations, and self-efficacy about science learning were very low compared with the students in other OECD countries (OECD, 2007, 2014). One distinctive effort to improve science and mathematics education in Korea is a national curriculum reform and government policy to integrate science, technology, engineering, arts, and mathematics (STEAM). Since 2011, STEAM education has been implemented by the Korean government and became a crucial issue in the Korean education system (Kwon *et al.*, 2009; MEST, 2011, 2012; MOE, 2015, 2016; Sanders *et al.*, 2011).

The Korean national organizations and professional communities of STEAM education considered that the integrative approach among STEAM disciplines is an essential method to restructure school education (KOFAC, 2012a, 2012b). For example, the 2009 and 2015 Revised National Science Curriculum strongly recommended the importance of integration and STEAM as a core concept of the STEM disciplines (MEST, 2011, 2012; MOE, 2015). Moreover, according to KOFAC (2011), the implementation of STEAM education in Korea could enhance students' interests and problem-solving skills and contribute to improve the global literacy for a new global era (MEST, 2012). STEAM education refers to integrated approaches that situate the teaching and learning of STEAM content and process in the context of creative design problems and challenges. Furthermore, STEAM education, which presents instructional integration of STEAM disciplines, has been recently spotlighted in science and technology education (Jeong & Lee, 2017; Kwak & Ryu, 2016; Lee *et al.*, 2011).

Previous studies reveal that STEM education improves students' interest, positive attitude, and academic achievement in STEM disciplines. In addition, STEM learning experiences increase students' motivation and real-world problem-solving skills in science and mathematics. Students were found to better understand the scientific concepts, principles, and processes when they apply their knowledge into a practical situation including technological/engineering design and problem-solving activity (Becker & Park, 2011; Kwon & Lee, 2008). In addition, Korean STEAM education had a great impact on students' academic achievement and engagement in science classes (Kang, *et al.*, 2018; Kim, 2018; Shin, 2018). These programs helped improve students' creativity (Choi, 2017; Lee & Tae, 2017; Shin, 2018; Yoo *et al.*, 2016), scientific attitude (Yoo, *et al.*, 2016), interest in science, convergent problem-solving, and logical thinking skills (Lee & Tae, 2017).

Although the documents related to STEM/STEAM education provide impressive and revealing effective factors and outcomes, only a few studies have been conducted that explore an international comparison of students' motivation in science. In particular, there is no research that analyzes the effectiveness of mathematics, engineering, and science achievement (MESA) program as a STEM education to provide implications for science and STEM/STEAM teaching and learning.

This exploratory study focuses on the MESA program as a STEM program that includes engineering design processes and challenging task. MESA's major objective is to develop academic self-confidence and motivation of underrepresented students to study mathematics, science, and other engineering concepts. The MESA program fosters early interest and motivation in math and science and prepares middle and high school students who wish to pursue STEM majors in college. The MESA center is housed at a university with ties to university faculty members. Efforts are currently in place to increase the participation of underrepresented students through MESA school programs. However, despite these efforts, there remains a lack of scientific research that effectively assesses students' motivation in science.

This exploratory research focuses on identifying the MESA program's quantitative evidence of its influence on students' motivation in science. In addition, this study investigates how the MESA program influences the motivation in science of Korean gifted and talented students. It will provide an insight into science motivation issues in STEM education. Moreover, the findings of this study could contribute to the development of design-based engineering programs in terms of motivation in science and STEM career choice.In particular, the study is designed to explore middle school students' motivation in science between Korea and the USA with the following research contents:

1. Validate the Science Motivation Questionnaire (SMQ) items developed by Glynn (2009) in order to measure the science motivation of middle school students.

2. Analyze and discuss country and gender differences among SMQ factors.

Ⅱ. Research Method

1. Participants and Context

The participants of this study included 171 US middle school students who participated in the MESA program and activities in Utah, USA. The MESA education program focuses on engineering enrichment and academic preparation that supports educationally disadvantaged students by providing opportunities for minority students to succeed in STEM disciplines (Kane, *et al.*, 2004; Packernham, *et al.*, 2018). In addition, 200 Korean secondary students who enrolled in the

STEM program at a university institute for gifted and talented students were invited to participate in this study. These Korean students participated in the revised MESA program (e.g., Windmill Energy Challenge and Green Power Solar Car) as summer STEM camp. The research is conducted in an informal learning environment, working collaboratively with the engineering enrichment efforts (e.g., engineering design process) of the MESA program.

A total of 371 secondary students (216 male and 155 female students) who participated in the MESA program were invited for this study. The students' participation was voluntary and consistent with the procedures of the university research review boards. They were informed that their participation will help improve the MESA program as a STEM program.

2. Instrument

In the study, a measurement tool was used to test the validity of SMQ items (Glynn, 2009) several times. SMQ was originally developed to measure college students' science motivation; however,this has been used in several studies that measure middle or high school student's science motivation (Bryanetal., 2011; Ha & Lee, 2012; Ha *et al.*, 2012a, 2012b).

As presented in Table 1, the SMQ is composed of 30 items under the following subscales: intrinsic motivation (10 items), self-efficacy (9 items), self-determination (4 items), career motivation (2 items), and grade motivation (5 items). The students responded to each of these 30 randomly ordered items on a Likert-type scale of temporal frequency: never (1), rarely (2), sometimes (3), often (4), or always (5). This questionnaire took approximately 25 minutes to complete. Data were collected after the completion of the MESA program. The reliability of the items was measured using Cronbach's alpha with the following results: $\alpha = .89$ for the final 25 items used in this study and $\alpha = .70 - .88$ for the subscales. This result is very consistent with or slightly higher than the value of Glynn (2009).

3. Data Analysis

1) Exploratory Factor Analysis (EFA)

The exploratory factor analysis (EFA) was used to examine the SMQ factor structure and validity of the items. To produce the final factorial solution from the initial 30 items, several EFAs were performed on the data (using “principal axis factoring,” the common factor analysis, followed by oblimin rotation “promax”). For the validity of the items belonging to the subfactors, a factor loading of .3 or higher was selected. Cross-loading items or low-reliability items were deleted through a study conference with a collaborator.

2) Confirmatory Factor Analysis

The factor structure of the SMQ was examined using confirmatory factor analysis (CFA; Figure 1). The model fit was assessed using the chi-squared value (x^2), comparative fit index (CFI; Bentler, 1990), the Turker-Lewis index (TLI), and root mean square error of approximation (RMSEA; Browne & Cudeck, 1993). Given

Table 1. Science Motivation Questionnaire (SMQ)

Item No.	
Factor 1. Intrinsic motivation	
22	I find learning the science interesting.
1	I enjoy learning the science.
25	The science I learn has practical value for me.
23	The science I learn is relevant to my life.
16	The science I learn is more important to me than the grade I receive.
2	The science I learn relates to my personal goals.
27	I like science that challenges me.
30	Understanding the science gives me a sense of accomplishment.
19	I think about how I will use the science I learn.
11	I think about how the science I learn will be helpful to me.
Factor 2. Self-efficacy and assessment anxiety	
4	I am nervous about how I will do on the science tests.
13	I worry about failing the science tests.
6	I become anxious when it is time to take a science test.
28	I am confident I will do well on the science tests.
14	I am concerned that the other students are better in science.
29	I believe I can earn a grade of "A" in the science course.
18	I hate taking the science tests.
24	I believe I can master the knowledge and skills in the science course.
21	I am confident I will do well on the science labs and projects.
Factor 3. Self-determination	
8	I put enough effort into learning the science
26	I prepare well for the science tests and labs
9	I use strategies that ensure I learn the science well
5	If I am having trouble learning the science, I try to figure out why
Factor 4. Career motivation	
17	I think about how learning the science can help my career
10	I think about how learning the science can help me get a good job
Factor 5. Grade motivation	
3	I like to do better than the other students on the science tests
7	Earning a good science grade is important to me
12	I expect to do as well as or better than other students in the science course
15	I think about how my science grade will affect my overall grade point average
20	It is my fault, if I do not understand the science

that the x^2 value is sensitive to sample size (Byrne,1989), we used the x^2 / df fit with $x^2 / df = 1 - 3$ indicating a reasonable fit (Carmines & McIver, 1981). The CFI and TLI values of .90 or greater also indicate a reasonable fit (Kline, 2005; Marshetal. 2004; Bentler & Bonett, 1980). Furthermore, an RMSEA value of less than .08 denotes a

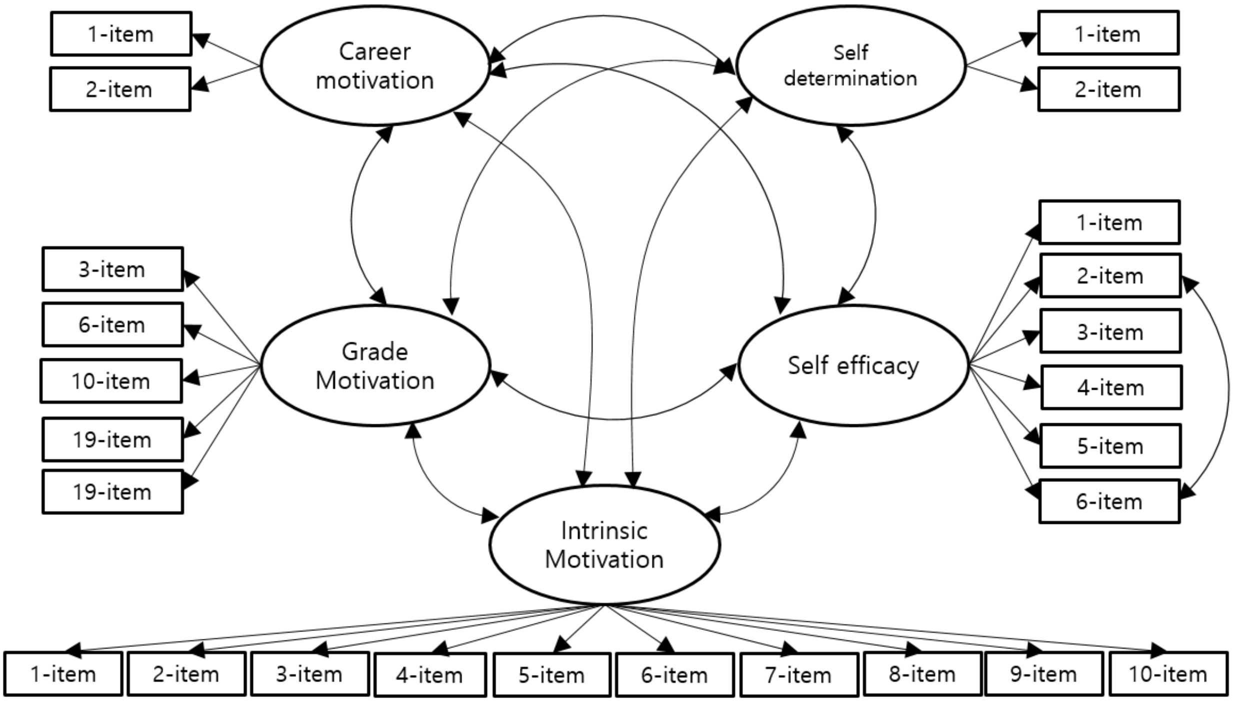

Figure 1. Structural equation model

good model fit (Browne & Cudeck, 1999). Scale reliability was calculated on the basis of the composite reliability index for SMQ subscale that reflects the proportion of shared variance to error variance in a construct.

3) Latent Mean Analysis

Mean and covariance structure analyses were used to test for latent mean differences for each needed satisfaction construct. The latent mean value for the male students was always constrained to zero, whereas it was freely estimated for the female students sample. It was only possible to obtain a comparison latent mean difference after comparing the two models of strong invariance.

4. Limitation of the Study

This study had limited access to students who experienced MESA STEM program from two countries, Korea and the USA. While the Korean students were from a gifted and talented population, the MESA students in Utah, USA were from underrepresented populations. Because we could not find underrepresented Korean students with exposure to the MESA STEM program, this exploratory study collected data from the two groups with similar STEM experiences. This study discusses the differences in the populations in order to better understand the comparison of the two groups.

Ⅲ. Research Method

1. Exploratory Factor Analysis and Reliability Analysis

The validity of the items was tested using EFA. The screen test for the final EFA implies the extraction of five factors, namely intrinsic motivation, self-efficacy, grade motivation, career motivation, and self-determination with the rotation sum of squares values of 6.27, 6.22, 5.22, 2.72, and 2.96, respectively. This solution accounted for 93.5% of the total variance and showed a remarkable Kaiser-Meyer- Olkin measure of sampling adequacy (.935). Table 2 presents the factor pattern coefficients for the 25 items.

The three items in self-efficacy and two items in self-determination were determined to have lower than .4 reliability and lower than .3 factor loading value. Thus, these items were removed as a result of our study conference with a collaborator. However, the removed items have no

Table 2. Result of exploratory factor analysis: pattern matrix (*n* = 371)

Factor	Item no.	Result of EFA		
		Factor loading	Cronbach's-α	
Intrinsic Motivation	1	.87	.88	.89
	2	.69		
	3	.65		
	4	.65		
	5	.64		
	6	.56		
	7	.51		
	8	.50		
	9	.4		
	10	.35		
Self-efficacy	1	.77	.83	
	2	.72		
	3	.71		
	4	.63		
	5	.62		
	6	.54		
Grade motivation	1	.78	.86	
	2	.71		
	3	.70		
	4	.69		
	5	.45		
Self-determination	1	.63	.70	
	2	.58		
Career motivation	1	.84	.71	
	2	.70		

Unweighted Least Square: IM - 6.270, SE - 6.224, GD - 5.224, SD - 2.960, CM - 5.716

significant effect on the comparison result of students' science motivation. The CFA was then conducted on the remaining 25 items.

These 25 items had their highest coefficients (on their respective factors) ranging from .35 to .87. The five-factor solution confirmed the results that emerged from the first version of SMQ. The five retained sub-scales showed good internal consistency. The standardized Cronbach's α values were .89 for the intrinsic motivation subscale, .88 for the self-efficacy subscale, .83 for the grade motivation subscale, .86 for the self-determination subscale and .70 for the career motivation subscale.

2. Descriptive Statistics

The mean, SD, and t-test values for all sub-factors of instruments are presented in Table 3. On the basis of the region, Korean students had significantly higher intrinsic motivation, career motivation, self-determination, and grade motivation than US students. However, self-efficacy was significantly higher in US students. For the gender difference, the results indicated that male students had significantly higher intrinsic motivation, self-determination, and grade motivation than female students. However, self-efficacy was higher in female students than male students, but not significant. To

Table 3. Means, standard deviations, and t-test for country and gender.

	Korea (*n* = 200)		USA (*n* = 171)		t-test result
	M	*SD*	*M*	*SD*	*t*
IM	45.48	4.74	39.72	6.88	-9.47***
CM	8.83	1.43	8.03	7.96	-4.54***
SE	18.41	5.94	22.02	5.63	5.97**
SD	8.78	1.37	8.29	1.69	-3.06***
GM	22.33	3.08	20.22	3.88	-5.80***
	Male (*n* = 216)		Female (*n* = 155)		t-test result
	M	*SD*	*M*	*SD*	*t*
IM	43.70	5.67	41.6	7.33	3.12**
CM	8.55	1.63	8.34	1.89	1.13
SE	19.72	6.08	20.56	6.04	-1.30
SD	8.72	1.40	8.32	1.69	2.46*
GM	21.80	3.33	20.74	3.92	2.80**

Note.
IM, intrinsic motivation; CM, career motivation; SE, self-efficacy; SD, self-determination; GM, grade motivation;
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

clarify the differences between regions and genders, the effect sizes (Cohen's *d*) were analyzed using latent mean analysis.

3. Confirmatory Factor Analysis and Model Fit

Through the EFA result, the five factors and 25 items measured by the instrument were tested for validity. For additional validity verification and latent mean difference measure, the structure of these relationships was analyzed using CFA on the sample data ($n = 371$). The analysis was conducted using AMOS 22.0 program to compare the goodness-of-fit statistics for the structural equation model (Figure 1), which is presented in Table 4. All statistics indicate good fit, suggesting that the 25 items of SMQ scale were theoretically meaningful and valid.

4. Latent Mean Analysis

1) Latent mean analysis on gender

Configural invariance, metric invariance, structural invariance, and equal factor variances/covariances were confirmed to verify the difference of SMQ factors according to gender (Table 5).

The fit of the baseline model (configural invariances) with free estimation of parameters was acceptable ($\chi^2 / df = 1.953$, CFI = .891, TLI = .876, RMSEA = .051). To verify equal intercepts, the model fit of the configural invariance and metric invariance models was compared. A comparison of the fit of the model reveals that it was almost of the same level ($\Delta \chi^2 / df = -.02$, ΔCFI = -.002, ΔTLI = .003, ΔRMSEA = -.001). There was no significant difference between the χ^2 values of the two models. In addition, TLI and RMSEA values were improved inequal intercepts. Moreover, the

Table 4. Result of model fit

	χ^2	*df*	χ^2 / df (1 - 3)	CFI (> .9)	TLI (> .9)	SRMR (< .08)	RMSEA (less .8)
Model	651.494	264	2.468	.916	.904	.073	.063

Table 5. Result of model fit on identity verification

	χ^2	*df*	χ^2 / df	CFI	TLI	RMSEA
Configural Invariance	1031.114	528	1.953	.891	.876	.051
Metric Invariance	1059.262	548	1.933	.889	.879	.050
Structural Invariance	1097.843	573	1.916	.886	.881	.050
Equal factor variances/covariances	1113.806	578	1.927	.884	.880	.050

metric invariance has been established; hence, the structural invariance was verified. The model fit of the two models (metric invariance and structural invariance) was compared. A comparison of the fit of the model reveals that the model fit was almost of the same level ($\Delta\,\chi^2 / df$ = -.017, Δ CFI = -.003, Δ TLI = +.002, Δ RMSEA = -.000). There was no significant difference between the χ^2 values of the two models. In addition, TLI value was improved instructural invariance; hence, the observed mean difference reflected the actual difference in latent variable.

To compare the latent mean by gender, the latent mean of male students was set to zero. To calculate Cohen's *d*, the equal factor variances/covariances were verified because if the two groups have the commonness of latent variance, a common standard deviation is applied. In Table 5, equal factor variances/covariances were verified ($\Delta\,\chi^2 / df$ = .017, Δ CFI = .002, Δ TLI = -.001, Δ RMSEA = .000).

Consequently, Cohen's *d* was calculated with a common standard deviation. As a result of latent mean difference, male students were found to have higher intrinsic motivation, career motivation, grade motivation, and self-determination than female students. However, female students have higher self-efficacy than male students (Table 6).

There is a very small difference in self-efficacy and career motivation between male and female students as supported by Cohen's *d* comparison. However, in intrinsic motivation, grade motivation, and self-determination, there is a medium difference according to gender.

Table 6. Result of latent mean analysis on gender

	Male	Female	Cohen's *d*
Intrinsic motivation	0	- .246	.47
Career motivation	0	- .121	.21
Self-efficacy	0	.151	.11
Grade motivation	0	- .229	.43
Self-determination	0	- .188	.35

Table 7. Result of model fit on identity verification

	χ^2	*df*	χ^2 / df	CFI	TLI	RMSEA
Configural Invariance	1089.908	528	2.064	.876	.859	.054
Metric Invariance	1148.185	548	2.095	.869	.855	.054
Structural Invariance	1268.488	568	2.233	.846	.837	.058
Equal factor variances/covariances	1304.668	573	2.277	.838	.831	.059

In other words, male students have significantly higher intrinsic motivation, grade motivation, and self-determination than female students SMQ. Furthermore, a significant difference exists in career motivation between the male and female students.

2) Latent mean analysis on country

Configural invariance, metric invariance, structural invariance and equal factor variances/covariances were confirmed to verify the difference in SMQ factors according to country (Table 7).

In the regional difference analysis, the values of the baseline model parameters were lower than that of the gender difference analysis. However, there was a significant difference in the t-test results at significance level .01. Moreover, considering the values of several parameters, it was judged to be a sufficiently analytical value. The fit of the baseline model (configural invariances) with free estimation of parameters was acceptable ($\chi^2 / df = 2.064$, CFI = .876, TLI = .859, RMSEA = .054). To verify equal intercepts, the fit of the two configural invariances and metric invariance models was compared. The comparison reveals the model fit was almost of the same level ($\Delta \chi^2 / df = .031$, ΔCFI = -.007, ΔTLI = -.004, ΔRMSEA = .000). There was no significant difference between the χ^2 values of the two models.

Moreover, the metric invariance has been established; hence, the structural invariance was verified. The fit of the two metric invariance and structural invariance models was compared. The comparison reveals that the model fit was generally of the same level ($\Delta \chi^2 / df = .138$, ΔCFI = -.023, ΔTLI = -.018, ΔRMSEA = .004). The difference between the χ^2 values of the two models was not significant; therefore, the observed mean difference reflected the actual difference in latent variable.

To compare the latent mean by region, the latent mean of students from the USA was set to zero. Moreover, to calculate Cohen's *d*, the equal factor variances/covariances need to be verified because if the two groups have the commonness of latent variance, a common standard deviation is applied. In Table 7, equal factor variances/covariances were verified ($\Delta \chi^2 / df = .047$, ΔCFI = -.008, ΔTLI = .006, ΔRMSEA = .001).

Consequently, Cohen's *d* was calculated with common standard deviation. Result of the latent mean difference reveals that Korean students had higher intrinsic motivation, career motivation, grade motivation, and self-determination than US students. However, US students have medium-high self-efficacy compared with Korea students (Table 8).

The difference in self-efficacy was derived to be medium as supported by Cohen's *d* comparison. There is a high degree of differences for the other factors between the USA and Korea. The result of latent mean difference analysis shows that Korean students have significantly higher intrinsic motivation, career motivation, grade motivation, and self-determination than USA students. However, self-efficacy was moderately higher among US students than Korean students.

Table 8. Result of latent mean analysis on region

	USA	Korea	Cohen's *d*
Intrinsic motivation	0	.649	1.27
Career motivation	0	.537	.95
Self-efficacy	0	-.683	- .49
Grade motivation	0	.458	.78
Self-determination	0	.216	.58

Ⅳ. Conclusion and Discussion

This exploratory study is aimed at exploring the validity of the SMQ items, which were originally developed for university students, in order to measure science motivation of middle school students and to analyze gender and country differences of SMQ factors. The major results in this study are as follows.

First, EFA was used to examine the factor structure and validity of the SMQ items. The five-factor solution confirmed the results of this study's factor solution which is consistent with the first version of SMQ. The five retained subscales showed good internal consistency. Previous studies revealed that SMQ had good content validity and criterion-related validity for science and nonscience majors (Glynn *et al.*, 2007, 2009). In the present study, the 25 items of the SMQ scale were theoretically and practically meaningful instrument to assess the latent motivational variables of middle school students. Moreover, the questionnaire is an efficient tool for assessing the components of middle school students' motivation and their science achievement that may be influenced by this motivation (Glynn *et al.*, 2011).

Second, the latent mean difference by gender indicated that male students have higher intrinsic motivation, career motivation, grade motivation, and self-determination than female students. For the self-efficacy factor, female students were higher than male students. In earlier studies (Britner, 2008), female high school students reported stronger self-efficacy in Earth Science classes. In middle school, mastery experiences were only significant predictor of academic self-efficacy for male and female students (Britner & Pajares, 2006). However, the SMQ can be a source of self-efficacy in science to collect evidence for gender differences in middle schools.

Third, a result of latent mean difference showed a significant difference in intrinsic motivation, career motivation, grade motivation, and self-determination between Korea and USA, revealing that Korean students were higher than US students in terms of the four factors. However, US students have medium-high self-efficacy compared with Korean students.

The MESA students in Utah were from the underrepresented populations, which may have impacted their motivation and exposure to STEM fields. While the Korean students were from the gifted and talented population, which may have afforded these students with increased exposure to STEM fields and thereby increasing their self-determination. Higher self-efficacy for the US students and the higher motivation and determination of the Korean students is interesting to the researchers. It would seem that if Korean students had high motivation they would see themselves as capable in STEM.

According to Song (2014), gifted students from low-income families showed low mathematical attitudes and scientific attitudes when compared with gifted students from non-low-income families. STEM education can lead to improvement of scientific motivation and scientific attitude of gifted students from low-income families. It is suggested that future research could be conducted to determine whether the emphasis on STEM by location and socioeconomic status impacts the motivation factors felt by students and explore the reasons for the differences in motivation between the two countries in conjunction with qualitative methods.

References

American Association for the Advancement of Science [AAAS]. (2001). *Atlas of science literacy I*. New York, NY: Oxford University Press.

American Association for the Advancement of Science [AAAS]. (2007). *Atlas of science literacy II*. New York, NY: Oxford University Press.

Becker, K., & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM education, 12*(5/6), 23-37.

Bentler, M., & Bonett, G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin, 88*, 588-606.

Bentler, M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*, 238-246.

Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in Life, Physical, and Earth Science classes. *Journal of Research in Science Teaching, 45*(8), 955-970.

Browne, M., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen, & J. S. Long [Eds.], *Testing structural equation models*. Newbury Park: Sage.

Bryan, R., Glynn, S., & Kittleson, J. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Science Education, 95*, 1049-1065.

Byrne, M. (1989). *A primer of LISREL: Basic applications and programming for confirmatory factor analytic models.* New York: Springer-Verlag.

Campbell, T., Lee, H., Kwon, H., & Park, K. (2012). Student motivation and interests as proxies for forming STEM identities. *Journal of the Korean Association for Science Education, 32*(3), 532-540.

Carmines, E., & McIver, J. (1981). Analyzing Models with Unobserved Variables: Analysis of Covariance Structures. In G. W. Bohrnstedt, & E. F. Borgatta (Eds.), *Social measurement: Current issues*. Beverly Hills, CA: Sage.

Choi, E. (2017). Study on how art-centered STEAM program influences the learner´s creativity. *Journal of Art Education, 48*(0), 187-223.

Glynn, S., Taasoobshirazi, G., & Brickman, P. (2007). Nonscience majors learning science: A theoretical model of motivation. *Journal of Research in Science Teaching, 44*(8), 1088-1107.

Glynn, S., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching, 46*(1) 127–146.

Glynn, S., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching, 48*(10), 1159–1176.

Jeong, H., & Lee, H. (2017). Development and application of scientific inquiry-based STEAM education program for free-learning semester in middle school. *Journal of Science Education, 41*(3), 334-350.

Jung, J., Jeon, J., & Lee, H. (2015). Domestic and international experts' perception of policy and direction on STEAM education. *Journal of Science Education, 39*(3), 358-375.

Kane, M. A., Beals, C., Valeau, E. J., & Johnson, M. J. (2004). Fostering success among traditionally underrepresented student groups: Hartnell College's approach to implementation of the Math, Engineering, and Science Achievement (Mesa) program. *Community College Journal of Research and Practice, 28*(1), 17-26.

Kang, N.-H., Lee, N., Rho, M., & Yoo, J. (2018). Meta analysis of STEAM (Science, Technology, Engineering, Arts, Mathematics) program effect on student learning. *Journal of the Korean Association for Research in Science Education, 38*(6), 875-883.

Kim, J. (2018). A study on the effects of science education STEAM program on augment reality for intellectual disabilities. *Journal of Mental Retardation, 20*(3), 151-175.

Kline, B. (2005). *Principles and practice of structural equation modeling* (2nd ed.). New York, NY: The Guildford Press.

Korea Foundation for the Advancement of Science & Creativity [KOFAC]. (2012a). *Teacher training program for STEAM education*. Seoul, Korea: Author.

Korea Foundation for the Advancement of Science & Creativity [KOFAC]. (2012b). *Introduction of STEAM education policy.* Seoul, Korea: Author.

Kwak, H., & Ryu, H. (2016). Analysis on the research trends in STEAM education. *Journal of Science Education, 40*(1), 72-89.

Kwon, H., & Lee, H. (2008). Motivation issues in the science, technology, engineering and mathematics (STEM) education: A meta-analytic approach. *Secondary Education Journal, 56*(3), 1-22.

Kwon, H., Park, K., & Lee, H. (2009). Research trends on the integrative efforts in technology education: Reviews of the relevant journals.

Secondary Education Journal, 57(1), 245-274.

Kuenzi, J. J. (2008). *Science, Technology, Engineering, and Mathematics (STEM) Education: Background, federal policy, and legislative action*. Congressional Research Service Report for Congress (RL33434).

Ha, M., & Lee, J. (2012). Exploring the structure of science motivation components and differences in science motivation in terms of gender and preferred track. *Secondary Education Research, 60*(1), 1-20.

Ha, M., Kim, M., Park, K., & Lee, J. (2012a). The analysis of differences in structure of natural science high school students' science learning motivation in terms of school year and gender. *Secondary Education Research, 60*(2), 365-384.

Ha, M., Kim, M., Park, K., & Lee, J. (2012b). The analysis of level and structure of natural science high school students' science motivation compared to general high school students'. *Journal of the Korean Association for Science Education, 32*(5), 866-878.

International Technology Education Association [ITEA]. (2003). *Advancing excellence in technological literacy: Student assessment, professional development, and program standards*. Reston, VA: Author.

International Technology Education Association [ITEA]. (2005). *Technological literacy for all.* Reston, VA: Author.

Jeon, J., & Lee, H. (2015). The development and application of STEAM education program based on systems thinking for high school students. *Journal of the Korean Association for Science Education, 35*(6), 1007-1018.

Lips D., & McNeill, J. B. (2009). A new approach to improving Science, Technology, Engineering, and Math education. *Backgrounder*, *2259*, 1-10.

Lee, E., & Tae, J. (2017). The effect of STEAM program based on design thinking on primary school pupil's convergent problem solving & interest in math-science. *Journal of Curriculum Integration, 11*(1), 143-162.

Lee, H., Kwon, Y., Oh, H., Lee, H. (2011). Development and implementation of engineering design and scientific inquiry based STEM education program. *Korean Journal of Teacher Education, 29*(3), 301-326.

Marsh, W., Hau, K., & Wen, Z. (2004). In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. *Structural Equation Modeling, 11*(3), 320-341.

Ministry of Education, Science and Technology [MEST]. (2011). *2012 MEST policy report*. Seoul, Korea: Author.

Ministry of Education, Science and Technology [MEST]. (2012). *Science Curriculum. Notification No.2011-361 of the MEST*. Seoul, Korea: Author.

Ministry of Education [MOE]. (2015). *the 2015 revised national curriculum.* Ministry of Education. Sejong, Korea: Author.

Ministry of Education [MOE]. (2016). *STEAM education.* Ministry of Education. Sejong, Korea: Author.

National Academy of Engineering [NAE]. (2004). *The engineer of 2020: Visions of engineering in the new century.*

Washington, DC: National Academies Press.

National Academy of Engineering [NAE]. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, DC: National Academies Press.

National Research Council [NRC]. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core Ideas*. Washington, DC: National Academy Press.

National Research Council [NRC]. (2013). *Next generation science standards: For states, by states*. Washington, DC: National Academy Press.

National Council of Teachers of Mathematics [NCTM]. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Organization for Economic Cooperation and Development [OECD]. (2007). *PISA 2006 Science Competencies for tomorrow's world. Volume 1: Analysis*. Paris, France: Author.

Organization for Economic Cooperation and Development [OECD]. (2014). *PISA 2012 results: What student know and can do – student performance in mathematics, reading and science (Volume Ⅰ, Revised edition, February 2014)*. Paris, France: Author.

Packenham, E., Balls, M., & Reiter, D. (2018). Helping students succeed in high school and on the post-secondary pathway: A report on the USU STARS! I GEAR UP program. *Asia Pacific Journal of Educational Research, 1*(1), 17-29.

Park, H.-W., & Shin, Y.-J. (2012). Effects of science lesson applying STEAM education on self-efficacy, interest, and attitude towards science. *Biology Education, 40*(1), 132-146.

Sanders, M. (2009). STEM, STEM Education, STEMmania. *The Technology Teacher*, December/January, 20-26.

Sanders, M., Kwon, H., Park, K., & Lee, H. (2011). Integrative STEM (science, technology, engineering, and mathematics) education: Contemporary trends and issues. *Secondary Education Research, 59*(3), 729-762.

Shin, M. (2018). Meta-analysis of the effects on the STEAM program for elementary school students. *Journal of Curriculum Integration, 12*(2), 47-66.

Son, M., Jeong, D., & Choi, W. (2017). Effects of nano-science based STEAM programs on the affective aspects of students under free semester courses. *School Science Journal, 11*(1), 77-89.

Song, K. (2014). The relation of intelligence, self-esteem, mathematical attitudes, and scientific attitudes of gifted students from low-income families. *Journal of Gifted/Talented Education*, *24*(6), 1039-1051.

Williams, J. (2011). STEM Education: Proceed with caution. *Design and Technology Education, 16*(1), 26-35.

Yoo, M., Park, G., Choi, J., Lim, M., Lee, J., Shin, M., Lee, C., Lee, Y., Yu, H., & Chung, H. (2016). The development of appropriate technology theme STEAM program for the elementary students and its application effects on creative thinking activity, scientific attitude and leadership. *Journal of Science Education, 40*(2), 144-165.