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A LONGITUDINAL TRAJECTORY OF SCIENCE LEARNING MOTIVATION IN KOREAN HIGH SCHOOL STUDENTS

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Abstract. *This research examined longitudinal trajectories of Korean students' motivation to learn science using group-based trajectory modeling (GBTM). The changes in five motivational constructs were focused in this research: self-efficacy, intrinsic motivation, grade motivation, self-determination, and career motivation. In addition, the relationship between academic track of students and each trajectory group was examined. Using Science Motivation Questionnaire II, data from 255 male high school students were collected during five semesters. Longitudinal data were analyzed by GBTM.. Chi-square analysis was also conducted to examine the relationships between academic track and each trajectory. As a result, it was found that students shared the same trajectory patterns in self-efficacy. Otherwise, two distinct trajectory groups ('high' and 'low') were found in each four constructs. There were significant correlations between academic track and trajectory groups. The findings of this research suggest that Korean science educators need to consider individual student's longitudinal trajectory of motivation to provide better science teaching and learning.*

Keywords: *academic track, group based trajectory modeling, high school, longitudinal study, science learning motivation.*

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Introduction

Learners' learning motivation is one of essential factors to be considered in the teaching and learning process. For recent decades, learning motivation has received considerable attention because learning experiences and achievements are different qualitatively and quantitatively depending on learner's motivation (Bryan, Glynn, & Kittleson, 2011; Simpkins, Davis-Kean, & Eccles, 2006; Valentine, DuBois, & Cooper, 2004). In science education, there has also been an increased emphasis on the importance of learning motivation because positive motivation to learn science is directly associated with active engagement in science learning (Bryan et al., 2011). In long-term perspective, it could be a significant predictor for educational achievement (Murayama, Pekrun, Lichtenfeld, & vom Hofe, 2013). Moreover, motivated student has been emphasized as a necessary condition itself in successful education. Improving students' motivation to learn science turns to educational goal itself (Palmer, 2007). Thus, many science education researchers have been challenged to understand learning motivation and find ways to improve students' motivation to learn science.

Recent international assessments such as Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA) have revealed that Korean students have considerably low levels of motivation on science compared with students in other countries. For example, in TIMSS 2015, 8th grade Korean students' confidence in science level was ranked the fourth lowest and their interest in science was the lowest among participated countries. PISA 2015 results also showed that the level of motivation of Korean students to learn science was much lower than international average while their science achievement level was at the top of rank. This 'low internal motivation with high achievement' phenomenon rises as a serious issue in Korea as well as in science education field. Because it deviates from the finding in previous science education research studies that students with high motivation to learn science would have high science achievement and vice versa. This unfortunately brings huge challenge to Korean science educators.

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This phenomenon not only occurs in Korean students, but also in other East Asian countries such as Japan, China, and Taiwan (Chang, 2014; Ho, 2009). Therefore, various researches have tried to find the characteristics of East Asian students' motivation and to understand this odd phenomenon based on socio-cultural context. Previous research about East Asian students' motivation have revealed that students tend to have more extrinsic motivational factors such as grade or future career than other non-East Asian students (Zhu & Leung, 2011). Also, some studies have suggested that students' motivation is associated with their parents' high expectation and educational cultures in East Asia (Ho, 2009). These previous researches have focused on characteristics of East Asian students' motivation, especially the interactions between various cultural factors and motivational factors. Also, the majority of these researches were cross-sectional study using data from international assessment such as PISA or another international assessment results. However, to date, only a few studies have described how students' motivation to learn science has changed across time with a longitudinal aspect.

According to social cognitive theory (SCT) suggested by Bandura (1986), motivation is constructed and developed with numerous interactions among environmental, personal, and behavioral factors. Therefore, individual motivation to learn science could be changed differently through their own development rather than remain a stable state. For example, some students' motivation decreases steeply in a particular time, while the other students' one increases depending on the influence of learning environment and other factors. Finding out these diverse patterns and dynamic state of motivation would provide effective information to seek reasons why Korean students have very low motivation to learn science and how to efficiently improve it. Therefore, this research attempted to explore the longitudinal trajectory of Korean students' motivation to learn science. Studying the change of motivation would give us better understanding on the characteristics of Korean students' science learning motivation and maybe other East Asian students. At the beginning of the next section, a brief review about motivation to learn science was provided. Next, the background related to high school education in Korean context was reviewed. Then the method called as group-based trajectory modeling (GBTM), used to examine the existence of heterogeneous trajectory groups in our longitudinal sample, was introduced.

Literature Review

Science Learning Motivation

Learning motivation refers to the inner state that encompasses various cognitive and emotional factors which are aroused, directed, and sustained learning behaviors (Schunk et al., 2008; Wigfield, Cambria, & Eccles, 2012). Glynn, Brickman, Armstrong, & Taasoobshirazi (2011) have defined 'motivation to learn science' based on SCT as "an internal state that arouses, directs, and sustains science-learning behavior" (p.2). Five distinct constructs, namely self-efficacy, intrinsic motivation, grade motivation, self-determination, and career motivation, have been suggested as part of building motivation to learn science. Those five indicators have been empirically tested and validated by thorough research studies with science and non-science major students (Glynn et al., 2011) and high school students (Schumm & Bogner, 2016). Detailed theoretical definitions of each constructs are as follows.

First, self-efficacy refers to one's belief about their own ability to perform a specific task or reach a specific goal (Bandura, 1977). It was first suggested as the important factor in the self-regulation process of human behavior by Bandura (1977) based on SCT. Previous studies in science education have found that self-efficacy is positively associated with various outcomes, including science achievement (Bryan et al., 2011), individual identity as a scientist (Robnett, Chemers, & Zurbriggen, 2015).

Second, intrinsic motivation refers to perceived interest or enjoyment in the task itself not arousing from extrinsic factors such as grade and rewards (Ryan & Deci, 2000a). Not only enjoyment, but also curiosity and value of science learning are considered as intrinsic motivation because these factors can arouse inherent satisfaction in human behavior without external rewards (Glynn et al., 2011).

Third, self-determination refers to individual perceived autonomy during the task. It was first suggested by Ryan and Deci (2000b) in self-determination theory. This theory postulates that humans are organisms with an active tendency to pursue growth of themselves, and suggested that humans are motivated internally by the process of determining their autonomous behavior, rather than external rewards or pressure (Deci & Ryan, 1985). Several studies have found that self-determination is positively related with participation in academic activities and achievement (Diseth & Samdal, 2014; Evans & Boucher, 2015; León, Núñez & Liew, 2015; Ryan & Deci, 2000b).

Fourth, grade motivation is the motivation to learn to get a better science achievement score. Normally high

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score is regarded as external reward of learning, so grade motivation is often categorized as extrinsic motivation. It is known as one of important factors to be considered in understanding the academic motivation of East Asian students, because many people in East Asian culture have high value on achievement in education (Ho, 2009; Zhu & Leung, 2011; Zhou & Kim, 2006).

Fifth, career motivation refers to one's belief of relation between their learning behavior and future career. Students with high career motivation try to learn science for their future career. Glynn et al. (2007) suggested that non-science major students' motivation to learn science was associated with their perception about relevance between future career and science. And previous studies about East Asian students also revealed that perception on relevance between future career and learning have an important role in their learning as future-oriented motivation (Shin, Lee, & Ha, 2017; Chang, 2014; Zhu & Leung, 2011).

The effects of each motivational construct on academic achievement or value have been discussed differently in previous research studies (Ryan & Deci, 2000a). For example, some studies maintained that extrinsic motivation has a negative effect on learning, while others suggested that extrinsic motivation also has some positive effect on learning (Ryan & Deci, 2000a). For East Asian students, it is known that both external constructs such as grade motivation are much more closely related to their intrinsic motivation and achievement when compared to students in western countries (Zhu & Leung, 2011). Therefore, all these five constructs are useful for understanding Korean high school students' motivation to learn science in various aspects (Schumm & Bogner, 2016). For understanding of longitudinal characteristics of motivation to learn science, present research focused on changes of the five constructs over time with exploratory perspective rather than focusing on the value or educational effect of each constructs.

Science Learning Motivation in Korean High School Students

To understand the characteristics of Korean students' motivation, consideration of East Asian socio-culture is required first. One common cultural belief in East Asia is that students' achievement in education is closely associated with one's successful future life (Ho, 2009). Especially, it is a widespread belief that achievement in college entrance examination is directly or indirectly linked to students' future life such as career and social status. One historical background of this belief is the civil service selection system through competitive examination and formal education for preparing this examination which had been maintained for more than a thousand years in East Asian Confucian culture. Because this system was the legitimated social system for upward mobility in social hierarchy, it had been a widespread belief that studying for examination is closely related with one's future success (Marginson, 2011). Since the introduction of modern university system in Korea decades ago, entering prestigious university has been regarded as one step toward upper social and economic status (Marginson, 2011). Thus, many Korean high school students believe that they need to get good score in Korean college scholastic ability test (CSAT) for entering a prestigious university. In addition, within the collective familyism culture, parents believe that they have responsibility for children's education, and invest much in their children's education (Jerrim, 2015). Consequently, Korean parents are also devoted to their children's education. And they tend to have high expectation for their children's achievement.

On the one hand, such cultural background has a positive effect on students in terms of parents' support for education and high achievement. On the other hand, students feel pressured about their learning and their own achievement in examination. Especially, many high school students in Korean and other East Asian countries face many stress factors and anxiety in terms of college entrance examination (Liu & Lu, 2011; Nishimura & Sakurai, 2017). Given this context, their motivation in science learning could change dramatically rather than maintaining a steady state during high school period. However, the majority of studies about East Asian students' motivation are focused on elementary and middle school students, and there were few studies with high school students. Therefore, a longitudinal study is needed to uncover the complex characteristics of Korean high school students' motivation. Present research attempted to explore the changes in motivation over five semesters in high school (two and a half years) by assessing students' science motivation at the end of each semester.

Group-based Trajectory Modeling

Considering that one's motivation is constructed with various environmental and behavior factors around them, it is possible that science learning motivation trajectory of each student would not show the same patterns. Therefore, the heterogeneity of science motivation trajectory could exist in students. One of useful methods for identifying heterogeneity in longitudinal data is group-based trajectory modeling (GBTM) first introduced by Nagin (2005). GBTM is a useful method to explore empirically distinct patterns with different development over time from longitudinal data (Nagin & Odgers, 2010). While traditional longitudinal analyses have assumed homogeneity of all population or used arbitrary criteria to distinguish sub-groups in whole participants and then compared their trajectory patterns, GBTM makes it possible to empirically distinguish heterogeneous sub-groups with distinct trajectory patterns based on objective criterion index such as Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Based on these indexes, the best latent trajectory model which represents similarity and heterogeneity of individual trajectory could be identified (Nagin & Odgers, 2010). In addition, in GBTM, each student's membership in trajectory group is judged by probability of their membership in each identified group. Therefore, it is possible to examine the relationship between membership in trajectory group and students' other independent variables. These results from GBTM will provide meaningful information to develop efficient strategies to improve students' motivation to learn science.

Thus, considering possibility of heterogeneity in Korean high school students' science motivation trajectory and methodological usefulness of GBTM, the current research conducted GBTM analysis first to test whether there is a single change pattern or distinct change patterns of each science motivational constructs during high school. Based on the result of GBTM, each trajectory patterns in motivational constructs were explored.

Track System in Korean High School

Based on SCT, environmental factors have various reciprocal interactions with student's motivational factors. One such environmental factor to be noted in this research is academic track in high school. Generally, Korean high school requires students to choose one of two academic tracks, science and humanities, after the second semester of the first high school year. Depending on students' track choice, different educational curriculums and classes are provided for students. This choice is deeply related to their career paths and academic major in college. Previous research studies have found that track choice is influenced by students' academic motivation, achievement, and parents' suggestion (Shin, Lee, & Ha, 2017; Myeong & Crawley, 1993). Because different educational curriculum and activities related to career are provided, students' motivation and self-concept associated with science could be affected by their track choice. Thus, academic track is a notable variable to understand trajectory of science motivation. After identifying trajectory groups in science motivational factor using GBTM, this research examined the relationship between empirically identified trajectory groups and students' academic track.

While most Korean general high schools have the two-track system, the 'science core school' which is a special type of general high school has an additional track, 'science core track'. Starting from 2009, 100 Korean general high schools have been designated as 'science core school' for the purpose of fostering general high school students' scientific literacy and participation in STEM career (Shim et al., 2016). Educational aim of this school is similar to that of 'inclusive STEM school' in US which is established for students interested in science, not just for science-talented students (Means, Confrey, House, & Bhanot, 2008). In science core track, students could learn more advanced science subjects than students in other two tracks. There might be more various patterns in terms of science learning motivation in science core school with three kinds of academic track than in general high school with only two tracks. Thus, we selected science-core school students as participants in this research and examined the relationship between three tracks (humanities, science, and science core) and trajectory groups of science motivation.

Research Focus

Given the necessity of longitudinal study of science learning motivation and the possibility of existence of heterogeneous trajectory patterns in our longitudinal data, the present research has following three research questions.

Question 1: Do students show the heterogeneous longitudinal trajectory patterns in science learning motivation?

Question 2: How does science learning motivation of each identified trajectory group change over five semesters?

Question 3: Are the each identified trajectory group significantly related to the students' academic tracks (humanities, science, and science core) in high school?

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Methodology of Research

General Background

In order to find answers to research questions, this research conducted longitudinal research of high school students' motivation to learn science for two and a half years. For valid and reliable measurement of science learning motivation, item response theory based Rasch model analysis was conducted with collected longitudinal data. After examination of validity and reliability of measurement, GBTM analysis was performed to answer research questions 1 and 2. And Chi-square analysis was conducted for research question 3. A more detailed explanation of the methodology of research is as follows.

Sample of Research

Sample of research were 255 male students in one male science-core school in South Korea. Each participant was affiliated with one of three different tracks (Humanities, Science, and Science core track). 51% of these participants were affiliated with Humanities track, 27% were in Science track, and 22% were in the Science Core track. Due to regulation for collecting student's data, same number of students for other semesters couldn't be obtained as that (255) for the 1st semester. For the 2nd semester, we only obtained data from 136 students. For the 3rd semester, data from 237 students were collected. For the 4th semester, data from 223 students were collected. For the 5th semester, data from 198 students were collected.

Instrument

25 items of Science Motivation Questionnaire (SMQ) II developed by Glynn et al. (2011) were used for measuring motivation towards learning science. SMQ II measures the following five scales of motivation: intrinsic motivation, grade motivation, career motivation, self-efficacy, and self-determination. Each scale has five items with 5-Likert-type.

Data Analysis

To analyze longitudinal data, three steps of analyses were performed. First, multidimensional analysis based Item Response Theory (IRT)-Rasch model through Conquest V.4.5.0 was performed to examine the dimensionality of our data, to determine the validity and reliability of the instruments, and to convert ordinal data to interval data with plausible value. Once plausible value of every student was obtained, it was used to identify trajectory groups through performing GBTM analysis utilizing R package-software. Finally, cross tabulation test with Chi-square (χ^2) test was performed to examine the relationship between each trajectory groups and academic track. The analysis steps are summarized in Figure 1. Detail explanations of every step will be described in the following sections.

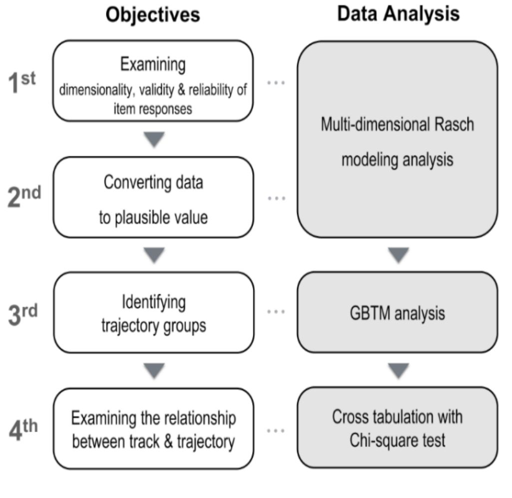

Figure 1. Steps and objectives of data analyses.

Confirming Dimensionality, Validity, and Reliability of Data

Prior to statistical analysis and further analysis, the validity of instrument construct was checked within our obtained data. IRT-Rasch analysis was performed in order to examine the validity of construct. The dimensionality of the instrument and the fitness of every item as well as Rasch-based reliability were determined. First, dimensionality test was performed to examine whether our data were fitted and supported by the five-dimension model proposed by Glynn et al. (2011). One-dimension model, two-dimension model, and five-dimension model were checked. The best one for data based on lower Final Deviance and Akaike Information Criterion (AIC) was chosen (Wu, Adams, Wilson, & Haldane, 2007). Our results indicated that the five-dimension model with Final Deviance = 48844.56 and AIC = 49074.56 was a better model compared to one-dimension or two-dimension model which had higher Final Deviance and AIC (Final Deviance = 54698.64 and AIC = 54900.64, Final Deviance = 51867.05 and AIC = 52073.05, respectively). Therefore, the five-dimension model was used.

Rasch model fit indices of each item are shown in Table 1. Both unweighted and weighted fit MNSQ met the cutoff values (0.7 to 1.4) of item fit indices for rating scale item. In addition, both PV-reliability and Cronbach's alpha of our data were very high, ranging from .89 to .95 for PV-reliability and from .94 to .96 for Cronbach's alpha. Another purpose of performing Rasch analysis is to convert ordinal data obtained from student to interval scale. Once multidimensional Rasch analysis is run, a set of student ability in every SMQ II construct (dimension) will be obtained. Thus every student will have five plausible-values (one for each dimension). These plausible-values were used for further analysis. All IRT-Rasch analyses were performed using Conquest V.4.5.0.

Table 1. Construct validity and reliability of SMQ II.

Construct	Item	Estimates	Unweighted Fit MNSQ	Weighted Fit MNSQ	PV-Reliability	Cronbach's alpha
Grade motivation	1	0.36	1.10	1.14	.95	.96
	2	-0.02	0.79	0.86		
	3	0.20	0.92	0.99		
	4	-0.10	0.89	0.96		
	5	-0.43	1.11	1.17		
Career motivation	1	-0.30	0.94	0.97	.91	.95
	2	-0.47	0.88	0.89		
	3	-0.39	0.93	0.97		
	4	0.52	1.16	1.19		
	5	0.64	1.36	1.38		
Self determination	1	-0.25	0.92	0.97	.89	.94
	2	-0.19	1.04	1.06		
	3	-0.47	0.96	0.98		
	4	0.50	1.10	1.14		
	5	0.42	1.08	1.13		
Self-efficacy	1	0.33	0.94	0.99	.93	.95
	2	0.31	0.94	0.98		
	3	-0.18	0.85	0.90		
	4	-0.28	0.87	0.91		
	5	-0.19	0.99	1.02		
Intrinsic motivation	1	-0.05	0.87	0.91	.92	.94
	2	-0.23	1.10	1.16		
	3	-0.24	1.22	1.25		
	4	0.16	0.97	1.01		
	5	0.37	0.96	1.01		

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Analyzing Group-based Modelling of Longitudinal Data

The next step is to uncover the number of latent groups lied in our sample based on the relationship between student motivation and semesters. GBTM was utilized to unveil the relationship. For computing GBTM, crimCV package, one of R-software packages, was used. CrimCV in R-package provides new methods for predicting the number of cluster or groups in longitudinal data by utilizing cross validation error methods (CVE). The most common method for examining the number of latent groups is by utilizing Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC). BIC and AIC also can be used as base to examine the number of latent groups for longitudinal data computed with other software. However, they often fail to compute the accurate maximum likelihood estimation (MLE). This could lead to the identification of incorrect number of groups for longitudinal data (Nagin, 2005). Thus, Nielsen et al. (2014) have developed a new method called crimCV by utilizing CVE methods. CVE method is better than AIC and BIC for examining the number of groups lied in longitudinal data because it can compute MLE more accurately. Nielsen et al. (2014) have recommended that lower CVE indicates better 'fit' of the data. Therefore, the model with the lowest CVE value was chosen as the best model in this research. Since AIC and BIC are the most widely used methods on indicating the fitness of a model, BIC and AIC values were also considered to decide the best model for our longitudinal data.

As aforementioned, we could not obtain the same number of participants for every period of data collection. This is a common problem faced by researchers who conduct longitudinal studies (Nagin & Odger, 2010). In order to tackle this problem, most longitudinal data processing procedures including crimCV have GBTM algorithm which provides some ways on predicting the missing data through maximum estimation. Every dimension was separately analyzed to find the best model from two groups until the lowest CVE was founded. Once the best model was found, the name of every group in the model based on the pattern of student's motivation for five semesters was given. CrimCV 0.9.3 in R Studio was used for GBTM analysis.

Examining Relationship between Track and Trajectory Groups

To explore whether groups obtained by GBTM were associated with student tracks, chi-square test based on cross-tabulation was performed. Phi test results were used as the effect size to indicate how big is the magnitude of every group associated with student tracks. With chi-square results, every trajectory group was characterized in more details. Chi-square analysis was performed using IBM SPSS Statistic version 22.

Results of Research

Identification of Latent Trajectory Groups

The first research question was whether there is a single trajectory pattern or distinct trajectory pattern of each science motivational construct. For this, this research examined the best number of latent group model which represented distinct patterns of change in each science motivational factor using GBTM. As mentioned above, CVE was used as the criterion for choosing the best trajectory. The results of GBTM are shown in Table 2. First, one group trajectory model was considered as the best model for examining changes in self-efficacy. In case of self-efficacy, CVE index of one group trajectory model was 3.75. However, CVE of a higher number group model could not be estimated. This means that these models are inappropriate to represent student trajectory. This result also indicates that all students share similar trajectory pattern in self-efficacy. Whereas, two-group model was considered as the best model for examining changes in self-determination, intrinsic motivation, grade motivation, and career motivation (CVE = 3.43; 3.50; 3.97; 3.82, respectively). All CVE of the two-group model were lower than those of the one group model in these four motivational factors. These results indicate that two groups of students have different patterns in self-determination, intrinsic motivation, grade motivation, and career motivation.

Table 2. Model fitness indices for various numbers of latent trajectory group model.

Motivational factor	Number of group	AIC	BIC	CVE
Self-efficacy	1	5312.78	5338.53	3.75
	2	5324.78	5381.44	-
	3	5319.22	5406.78	-
	4	5309.66	5428.12	-
Self-determination	1	5381.33	5407.09	3.74
	2	5300.14	5356.80	3.43
	3	5312.14	5399.70	-
	4	5324.14	5442.61	-
Intrinsic motivation	1	5280.61	5296.07	3.74
	2	5266.42	5302.48	3.50
	3	5259.25	5315.91	-
	4	5267.25	5344.51	-
Grade motivation	1	5808.88	5834.63	4.56
	2	5691.07	5747.73	3.97
	3	5822.98	5895.09	-
	4	5715.07	5833.54	-
Career motivation	1	5590.19	5615.95	4.39
	2	5504.81	5551.16	3.82
	3	5602.97	5690.54	-
	4	5529.51	5647.98	-

Exploration of trajectory patterns in each motivational constructs

In order to grasp a pattern of change in motivation, this research graphically represented the mean values of the motivational level of the each trajectory group identified through GBTM (Figure 2).

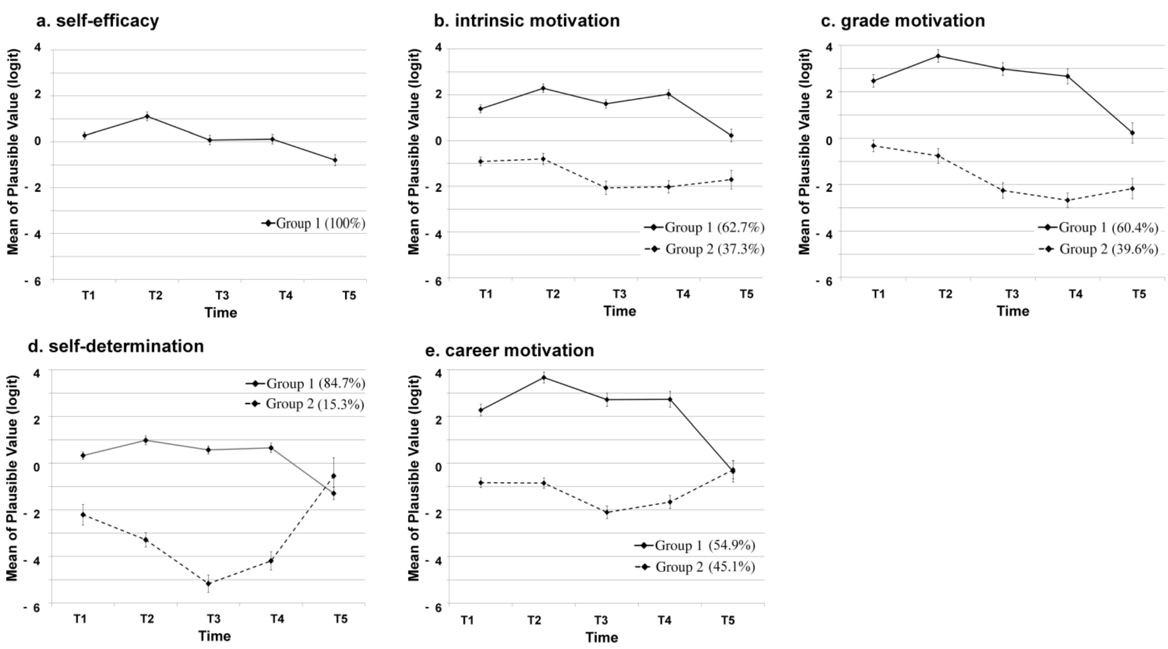

Figure 2. Trajectory patterns of students' science motivation.

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Self-efficacy. As mentioned above, there was no distinct group in self-efficacy trajectory. This indicates that students' change in self-efficacy during five semesters could be presented with only one trajectory. Figure 2-a shows the change of self-efficacy during five semesters based on one group trajectory model. The change pattern of self-efficacy was far from being linear. Students' self-efficacy was increased at the second semester. However, after that, the level of self-efficacy was gradually decreased, starting from the third semester to the fifth semester. As the result, the lowest level of self-efficacy was recorded in the fifth semester.

Intrinsic motivation. Latent trajectory groups of intrinsic motivation are depicted in Figure 2-b. The first group (62.7%) was comprised of students with a pattern of high intrinsic motivation. The other group was comprised of 37.3% students with a pattern of low intrinsic motivation. Therefore, two groups were named as "High IM (intrinsic motivation)" and "Low IM". The level of intrinsic motivation in High IM group fluctuated during five semesters. However, since the level in fifth semester has decreased drastically, overall level of intrinsic motivation in High IM has decreased. On the other hand, in the Low IM group, the level of intrinsic motivation in science showed a more stable pattern than High IM group during all five semesters. However, their intrinsic motivation level was decreased in the third semester. After that, similar level was kept until the fifth semester. Thus, overall level of intrinsic motivation in the Low IM has also decreased.

Grade motivation. Results of grade motivation of Latent trajectory groups are shown in Figure 2-c. The first group was comprised of 60.4% students with high grade motivation. The other group was comprised of 39.6% students with low grade motivation on science grade. Therefore, the two groups were named as "High GM (grade motivation)" and "Low GM" groups. The trajectory patterns in grade motivation were different between the High GM and Low GM groups. As shown in Figure 2c, grade motivation level in High GM group was increased at the second semester. After that, the level of grade motivation was decreased until the fifth semester. Especially, the level of grade motivation was decreased rapidly at the fifth semester. Whereas, in case of Low GM group, the level of grade motivation was decreased from the second semester and kept quite similar low level of grade motivation until the fifth semester.

Self-determination. Trajectory groups of self-determination are shown in Figure 2-d. The majority of students (84.7%) were indicated in the higher level of self-determination group. The rest of these students were included in the second group (15.3%) with low level of self-determination. Therefore, the two groups were named as "High SD (self-determination)" and "Low SD". The High SD group showed high and stable level of self-determination from the first to the fourth semester. However, their self-determination level was declined into lower than that of Low SD group in the fifth semester. On the other hand, the Low SD group showed different trajectory compared to the high SD group. Their self-determination was decreased from the second to the third semester. However, after the third semester, their self-determination level has gradually increased. Especially, it has significantly increased from the fourth until the fifth semester, making their SD level slightly higher than the High SD group at the fifth semester.

Career motivation. Results of career motivation of latent trajectory groups are shown in Figure 2-e. In case of career motivation, students were divided into two latent groups with almost the same ratio. The first group was comprised of 54.9% students with high science career motivation and the other group was comprised of 45.1% students with low science career motivation. Therefore, the two groups were named as "High CM (career motivation)" and "Low CM". In case of High CM, career motivation level fluctuated from the first to the fifth semester. It increased in the second semester and decreased slightly in the third and fourth semesters. However, the level of career motivation has decreased to a level similar to that of the Low CM group in the fifth semester. On the other hand, in Low CM, the level of career motivation has decreased in the third semester. After that, it has increased until the fifth semester. Finally, it reached a level similar to that of the High CM in the fifth semester.

Relationship between Trajectory Groups and Academic Track

To examine the relationship between trajectory groups and academic track, cross tabulation analysis of each trajectory group and track was conducted with chi-square test. The results of cross tabulation are shown in Table 3. The results for each construct are as follows.

Table 3. Cross tabulation of each trajectory group with academic track.

Constructs	Trajectory group	Academic track			Total	χ^2	Cramer's V
		Humanities (%)	Science (%)	Science Core (%)			
Intrinsic motivation	High	56(35.0)	52(32.5)	52(32.5)	160(100)	49.30**	.50
	Low	74(77.9)	18(18.9)	3(3.2)	95(100)		
Grade motivation	High	49(31.8)	53(34.4)	52(33.8)	154(100)	61.70**	.49
	Low	81(80.2)	17(16.8)	3(3.0)	101(100)		
Self-Determination	High	95(44.0)	66(30.6)	55(25.5)	216(100)	28.46**	.33
	Low	35(89.7)	4(10.3)	0(0)	39(100)		
Career motivation	High	39(27.9)	50(35.7)	51(36.4)	140(100)	72.06**	.53
	Low	91(79.1)	20(17.4)	4(3.5)	115(100)		

First, in intrinsic motivation, there were significant relationships between academic track and identified trajectory groups ($\chi^2 = 49.30$, $^{**}p < .01$, phi = .50). As mentioned above, of the 255 total participants in this research, 51% students were in humanities track, and 27% were in science track, and 22% were in science core track. The High IM group (n=160) was almost evenly comprised of science track students (32.5%), science-core track students (32.5%), and some humanities track students (35.0%). Compared with percentage of total group by academic track, the High IM was comprised of more science and science core track students. While majority of students in the Low IM (n=95) were humanities track students (77.9%). There were also some science track students (18.9%) and a few science core track students (3.2%).

Second, there was also significant relationship between latent trajectory groups of grade motivation and students' tracks ($\chi^2 = 61.70$, $^{**}p < .01$, phi = .49). The High GM group (n=154) was comprised of science-core track students (33.8%), science track students (34.4%), and humanities track students (31.8%). And like High IM group, there were much more science and science core track students in the High GM. On the other hand, the majority of students of the Low GM group (n=101) were humanities track students (80.2%). There were also some science track students (16.8%) and a few science core track students (3.0%).

Third, trajectory group of self-determination was significantly associated with track system ($\chi^2 = 28.24$, $^{**}p < .01$, phi = .33). The High SD group (n=216) consisted of science-core track students (25.5%), science track students (30.6%), and humanities track students (44.0%). On the other hand, the majority of students of the Low SD group (n=39) were humanities track students (89.7%). And there were some science track students (10.3%) in Low SD group, but no students in science core track.

Fourth, significant relationship between latent trajectory group of career motivation and student's track was found ($\chi^2 = 72.06$, $^{**}p < .01$, phi = .53). The High CM group (n=140) consisted of science-core track students (36.4%), science track students (35.7%), and humanities track students (27.9%). The Low CM group (n=115) mainly consisted of humanities track students (79.1%). There were also some science track students (17.4%) and science core track students (3.5%) in the Low CM group.

In sum, although there were some differences in trajectory patterns and the number of students, all four of the Low groups consisted mainly of humanities track students with a few science and science core track students. On the other hand, all four of High trajectory groups consisted more of science and science core track students than the Low group, but some humanities track students also were included.

Discussion

The main purpose of the present research was to explore longitudinal trajectory of Korean students' science motivation. To be specific, first, this research tested whether there is a single trajectory pattern or distinct trajectory pattern of each science motivational construct using GBTM. And based on these results, this research attempts to explore each change pattern of identified trajectory group. In addition, the relationship between identified trajectory group and academic track system in Korean high school was examined.

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GBTM results showed heterogeneous change patterns in high school students' motivation to learn science during five semesters. Except self-efficacy, each motivational construct had two different trajectories: high and low. Because trajectory analysis in each construct was conducted respectively in the present research, students had more diversity patterns considering the combination of group trajectories in each construct. For example, some students could be affiliated with the high trajectory group in all four constructs, while other students are affiliated with the high trajectory group only in grade motivation. In this case, there are 16 possible patterns to represent various students' science motivation development. Although this research did not focus on the exact combination, our results showed the potential that diverse change patterns might exist among students.

Results of GBTM with self-efficacy showed that one-group model was the best for explaining students' change in self-efficacy. This result means that all students have similar change patterns in self-efficacy. One possible reason is that reporting self-efficacy is strongly influenced by cultural context, not only by individual context (Klassen, 2004). Results of international assessment such as PISA and TIMSS have revealed that the level of self-efficacy is very low in Korean students and students in other East Asian countries sharing cultural context. Previous researches on this phenomenon have pointed out two reasons based on cultural context. First, East Asian culture with collectivism emphasizing modesty and harmony of community is closely related to students' self-efficacy. It has been a widespread belief that modesty is an important attitude to keep harmony of community in a collectivism culture (Kurman, 2003). With this background, it might be unnatural for students to report their confidence in science learning. Therefore, students tend to underestimate their self-efficacy with implicit cultural belief about modesty (Kagitcibasi, 1997). Second, as mentioned above, East Asian parents and communities tend to have very high expectation for students' achievement. Therefore, students might have low self-efficacy even though their achievement level is high. Given this cultural context, self-efficacy could be operated as 'cultural-specific variable' rather than 'individual-specific variable' for Korean students. In this regard, trajectory in self-efficacy appeared to have no big individual difference in changes over time.

Results of one-model trajectory analysis showed that self-efficacy increased slightly in the second semester. After that, it decreased until the fifth semester. The plausible reason for such decrease might be pressure from college entrance, especially Korean college scholastic ability test (CSAT). As was stated above, it is a widespread belief in Korea that grade in CSAT is a critical point to their future life's success and it is a very competitive examination. Not only students, but also their parents, family, and teachers treat this exam as a very important thing in student's life. This overwhelming environment might have caused students' self-efficacy fall down to the lowest. In addition, most of the fifth semester classes are only focused on preparation for CSAT. Thus, various educational activities which could give students a chance to experience sources of self-efficacy such as successful accomplishment or emotional arousal suggested by Bandura (1986) did not operate sufficiently in schools in the fifth semester. Therefore, it might be a hard environment for students to improve their self-efficacy during the fifth semester. Although self-efficacy is culturally specific, it is evident that Korean students' self-efficacy also plays an essential role in their learning behavior and outcomes. Therefore, various educational improvements from teaching strategies to college examination system should be made in Korea for students so that they could properly estimate their own ability and sustain their self-efficacy.

The findings showed that two-group model was the best for explaining students' changes in the other four constructs (self-determination, intrinsic motivation, career motivation and grade motivation) based on GBTM. High level groups of self-determination, intrinsic motivation, career motivation, and grade motivation mainly consisted of science and science track students, and they also had some of humanities track students. The common feature of trajectories in these four high level groups was that each level decreased a lot in the fifth semester as in the self-efficacy trajectory. Such high decline of the four motivational constructs could also be explained by the psychological pressure from CSAT.

However, unexpectedly, science grade motivation also decreased in the fifth semester. One possible reason to explain such decline might be due to 'learned helplessness' in individual students. Learned helplessness occurs when people perceive that they cannot avoid or control a stressful situation (Seligman, 1975). With lots of stress factors, people tend to be easily exhausted and they will lose their motivation to do things that they strived for. Many Korean third year (fifth and sixth semester) high school students might feel learning helplessness under pressure due to the competitive CSAT, thus losing their motivation to learn science, regardless of whether the pressure is internal or external.

No matter how many activities are conducted to improve students' motivation to learn science, if students' motivation eventually plummets at the end of high school, it is hard to say educational goal such as developing scientific literacy has been achieved. Therefore, various educational efforts are needed to sustain students' motivation to learn science. Given the inference that the decline in learning science motivation in the fifth semester is likely to be related to psychological pressure from CSAT, further researches are needed to shed light on the relationship between learning science motivation and various stress factors from competitive CSAT examination so that we can develop more efficient ways to sustain students' motivation to learn science during the overall high school period.

For groups with lower levels of the four constructs, majority of them are humanities track students with some students in science track. These four groups showed lower levels compared to students in the higher level groups in the first semester. However, there was a significant increase in the fifth semester in lower level groups of self-determination and career motivation (Low SD and Low CM). Especially, the Low SD group had higher self-determination level than the high SD group in the fifth semester. The exact reason for this phenomenon could not be determined in this research; however, one possible reason is change in belief about relevance of their future career with science. Previous research revealed that non-science major students' motivation to learn science is positively related with their belief in the relevance of science to their career (Glynn et al., 2007). Also according to previous research with Korean high school students, science career motivation is closely associated with their self-determination in learning science (Shin, Lee, & Ha, 2017). Considering these prior researches, change in thinking about career might be one reason for this phenomenon. However, further studies are needed to understand the clear reasons for this phenomenon.

What can be addressed in this research is that majority of students in low SD and CM groups are humanities track students. Although they chose humanities track with low self-determination and career motivation in science after the second semester, they showed unexpectedly high self-determination and career motivation in the fifth semester. Because science subject only takes up a small proportion in the curriculum of humanities track, some students in low SD and CM groups might not have obtained enough science educational support or information in school, even though they are motivated to learn science or have a career related to science. Our findings from chi-square tests between trajectory groups and track showed that the two classifications had significant relations in all four constructs. However, in terms of humanities track, two trajectory groups were mixed. These results showed that some students' motivation to learn science could change unexpectedly even after their track choice. In other words, some students' single decision on track could not coincide with their later change of motivation to learn science.

In Korean high schools, once students select their academic track, the class and curriculum are separated depending on track, and it is not easy for students to change their track again. Although some students in humanities track get more interested in science and have greater motivation to learn science, there is less opportunity for them to listen to sufficient science class than students in science track. Therefore, it is needed to conduct a flexible science education curriculum for students' increase in humanities track whose science motivation increases after their track decision. And in order to provide learning opportunities tailored to individual learning motivation, teachers and schools need to conduct constant monitoring on students' motivation even after students' academic track decision was finished. Information on individual students' changes in the motivation of science learning help teachers to make better guidance and provide better academic plan for their students.

Limitation and Future Direction

The following limitations of present research should be considered. First, some attrition occurred during the data collection period. Attrition is an inevitable situation in most longitudinal researches. Although statistical estimation was conducted in GBTM, we need to consider that missing rate might lead to biased parameter estimation. Deleting data with some missing data such as list-wise deletion method is more likely to lead to biased estimation with more loss of data. Therefore, we chose to analyze data with some attrition. However, for clear understanding about the development of science motivation, further studies with sufficient data through continuing data collection until students' graduation in high school are needed.

Second, participants were all male students. Therefore, it is hard to generalize the findings of this research to all high school students' motivational development. In addition, the effect of gender difference on motivational trajectory could not be examined in this research. Numerous studies have shown that motivation to learning science is closely related to gender. If GBTM is conducted with both genders, we will get more insights about motivational development in both genders. Thus, further researches with female students would be needed.

Third, this research used exploratory approach to understand the development of students' motivation in science learning. However, to understand individual change in motivation to learn science and specific context of this trajectory, more in-depth researches such as interview with qualitative perspective are needed.

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Conclusions

The present research attempted to explore trajectory of Korean students' motivation to learn science. Unlike traditional longitudinal studies, this research used GBTM to explore the diversity of changes of students' motivation to learn science across academic years. Our results showed trajectories with noticeable features based on changes of students' motivation to learn science. In addition, it was found that students' science motivation was not stable, but changeable through academic years. Moreover, the changes of students' motivation were different depending on constructs of science motivation. In sum, students showed diverse changes of motivation, although they were in the same curriculum, and our GBTM analysis could differentiate groups based on the trajectory of motivation.

To date, Korean science educators have tried to improve students' motivation to learn science and suggested many instructional strategies and educational policies. However, these efforts have not been conducted by considering individual students' motivations; but they have been conducted to all students en bloc. Thus, each student was not able to receive tailored advice based on their individual characteristics (e.g., trajectory of motivation). Consequently, students might not be able to improve their motivation in science. Korean science education researchers and curriculum developers need to consider individual student's trajectory of motivation to provide better science curriculum and learning. In this sense, longitudinal data and GBTM analysis can play a significant role. We collected our data using paper-and-pencil survey for this research. Collecting students' motivation data was not difficult. Most schools operate a learning management system for quick and easy online survey. Moreover, it takes only ten minutes for students to answer the SMQII questionnaire. Then, it should be convenient for school administers to do longitudinal data collection and data management. With these methods, more schools need to monitor students' motivation to learn science longitudinally and use these data to provide counseling for students.

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