

Relationship between R&E Activities and Mathematics and Science Academic Achievement of Science High School Students

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Abstract

This study investigated the academic achievement of science and high school students according to the characteristics of R&E activities in mathematics and science. In addition, based on the survey results, the correlation between R&E activity characteristics and mathematics and science academic achievement was studied through correlation analysis and factor analysis between subjects. There was a difference in academic achievement in mathematics and science according to the characteristics of the R&E activity area, and the experience of R&E activity was found to be closely related to the academic achievement of related subjects. Depending on the area of R&E activity, mathematical and scientific academic achievement was found to be two factors: mathematical logic and natural understanding. Natural understanding factors significantly influenced students' academic achievement in mathematics, physics, and life sciences, and mathematical logic factors significantly influenced the academic achievement of students in chemistry and earth science subjects. In particular, mathematical logic ability was concentrated in excellent physics class students, and natural understanding ability was concentrated in excellent life science class students. Since the characteristics of the R & E activity area greatly influence the academic achievement of mathematics and science, it will significantly contribute to the selection and operation of the R & E activity area of science high school students.

Keywords: Science high school, Factor analysis, Math and science achievement, R&E

1. INTRODUCTION

Science high schools were established in 1983 as particular purpose high schools to enhance international competitiveness in science and technology by discovering and fostering students with talents and aptitudes in mathematics and science. Science high schools organize and operate curricula centered on mathematics and science subjects to solve the problems of the equalization education policy and to provide gifted education per the purpose of establishment [1]. However, contrary to the initial purpose of establishment, there was much criticism that science high schools were transformed into a means to enter prestigious universities [2].

In order to improve society's negative view of science high schools, the Ministry of Education announced plans to develop science high schools, including the operation of a curriculum specialized in science high schools, the improvement of the professionalism of science high school teachers, and the expansion of research activities of science high school teachers and students [3]. Research and education (R&E) programs are

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included in detailed measures to expand research activities for science high school students. R&E is a program for gifted students and is an experience-oriented project-type educational method for scientific exploration. Since 2003, it has been developed as a representative program for science-gifted students and applied to new students at the Korea Science Gifted School [4], and has since been applied and spread to science high schools nationwide. R&E can be divided into actual scientific participation research and self-directed project-type research, depending on the type of operation [5]. Science high school students choose one of the mathematics and science subjects for R&E activities and conduct in-depth research on related fields as well as being exposed to the environment of in-depth learning related to the subject, so the R&E elective subjects are deeply related to their careers. For this reason, even in previous studies, subjects chosen by science high school students for R&E were classified as preferred subjects of the study subjects [6]. Therefore, the subjects that science high school students choose to engage in R&E activities will also be deeply related to their personal characteristics.

The personal characteristics of learners that affect academic achievement can be divided into internal and external factors. Internal factors include intellectual ability, thinking style, personality, and learning style, and external factors include synchronization, attitude, and educational environment [7]. From a different perspective, learner factors that affect academic achievement are sometimes divided into personal and environmental factors. In particular, high school students said that interest in subjects had a significant impact on academic achievement as the synergy of internal and external motivations for college entrance, the value and importance of the subject, and the accumulated competence were more strongly implied [8].

There are only a few examples of middle school or general high school students, such as the development of integrated teaching-learning materials or content analysis between most mathematics subjects and science subjects such as mathematics and science, mathematics and chemistry, mathematics and life sciences [9-11]. By analyzing the correlation between each subject in the academic achievement of mathematics and science for science high school students, it was confirmed that the correlation between subjects was higher in science high school than in general high school [12].

Among Gardner's multiple intelligences are logical-mathematical intelligence, which is the ability to solve logical problems or equations, and naturalist intelligence, which is the ability to define and classify types of natural phenomena [13]. Prior research has shown that these two intelligences are closely related to the achievement of gifted middle school students in mathematics and science subjects [14].

Science high school students show a concentration on tasks with an intense intellectual curiosity about their interests in their attitude toward the field of mathematics and science, and they tend to devote much time to specific subjects among mathematics and science subjects in the learning process. Since the difference in individual preferences for these specific subjects of science high school students dramatically influences the achievement of related subjects, the relationship between the object of interest and the achievement of science high school students can be confirmed through achievement analysis. However, so far, these studies have been insignificant.

2. RESEARCH METHODS

2.1. Object of study

This study analyzed the effect of the three-year (2009, 2013, 2018) R&E activity experience on academic achievement in mathematics and science. A correlation analysis was conducted between mathematics and science subject achievement to reveal the characteristics of science high school students' mathematics and science academic achievement. The subjects of this study were 296 first-year students of G Science High School located in Gyeongsangnam-do. The distribution of R&E activity according to the year of the study target student is shown in Table 1.

Table 1. Participants' Characteristics (N(%))

Year	R&E Class						Total
	Mathematics	Physics	Chemistry	Biology	Earth Science	Others	
2009	18(20.0)	20(22.2)	20(22.2)	20(22.2)	8(8.9)	4(4.4)	90(100)
2013	18(17.5)	18(17.5)	18(17.5)	15(14.6)	12(11.7)	22(21.4)	103(100)
2018	18(17.5)	18(17.5)	18(17.5)	18(17.5)	9(8.7)	21(20.4)	103(100)
Total	54	56	56	53	29	51	296

Others=Information + Converged Science Class

2.2. Academic achievement

For academic achievement, students who have experienced R&E activities for more than six months after entering science high school used the academic achievement of mathematics and science at the end of the second semester of the first year. Since there was a difference in the average and standard deviation of achievement by year for three groups with different periods, the achievement was converted into a standard score that could confirm the relative position by year.

2.3. Statistical processing

For statistical processing, the IBM SPSS Statistics 28 program and the Microsoft Office 16 Excel program were used. Descriptive statistics, cross-analysis, and one-way variance analysis (ANOVA) were performed to find out the relationship between R&E activity areas and academic achievement. The correlation between mathematics and science subjects was investigated through correlation analysis, and two factors were extracted from mathematics and science subject achievement through exploratory factor analysis. However, before performing factor analysis, the Kaiser-Meyer-Olkin (KMO) and Bartlett values, which check the sample fit, were checked to confirm whether they were suitable for factor analysis, and then the factors were extracted. In the case of academic achievement converted to standard scores, since there was no measurement error for the observed variable, the Principal Component Analysis method was used to extract factors, and Varimax perpendicular rotation was performed to increase discriminant validity and interpret factors.

2.4. Research questions

This study investigated the academic achievement of mathematics and science according to the characteristics of R&E activity areas in mathematics and science. Through correlation analysis and factor analysis between mathematics and science academic achievement, the correlation between each subject was investigated, and the characteristics of subject achievement are investigated. In particular, it is to investigate the characteristics of academic achievement according to the selected R&E activity area and to study the relationship between R&E activity area and science subject achievement. In order to achieve this research purpose, the following research questions were set up.

First, what is the academic achievement of mathematics and science according to the characteristics of the R&E activity area in mathematics and science?

Second, what is the correlation between each subject through correlation analysis and factor analysis of academic achievement in mathematics and science?

Third, what are the characteristics of the area of R&E activity and the characteristic factors of academic achievement in mathematics and science?

3. RESEARCH RESULTS

3.1. Academic achievement in mathematics and science according to the characteristics of R&E activity areas

G Science High School has opened and operated student-led R&E project research in the regular curriculum for the purpose of improving students' self-directed research skills such as scientific inquiry ability, creative problem-solving ability, cultivation of research attitude as a scientist, etc. Students are helped to develop their talents and aptitudes by experiencing the process of finding and solving problems on their own through R&E activities, and have valuable experiences for career choices. The R&E program is operated in six gifted classes, including mathematics, physics, chemistry, biology, earth science and information, and convergence science. The gifted class is a must-choose for all first-year students, and most of them are assigned to the gifted class they want to learn. Therefore, students choose the field of R&E activities in relation to the subjects they like and can do well, and through R&E activities, related subjects are exposed not only to in-depth research but also to an in-depth learning environment.

One-way ANOVA was performed to confirm the relationship between R&E activity area and science subject achievement, and the results are shown in Figure 1.

Mathematics class students showed above-average academic achievement (M: 0.263, SD: 0.733) in mathematics subjects but below-average academic achievement in the rest of the subjects. Physics class students showed the highest average of academic achievement in physics (1.280, 0.614), mathematics (0.830, 0.733), and earth science (0.464 and 0.743) subjects, and above average in chemistry and life science subjects. Chemistry class students showed the highest average of academic achievement (0.852, 0.638) in chemistry subjects and above-average academic achievement in mathematics, life sciences, earth sciences, etc., excluding physics subjects.

Biology class students showed the highest average of academic achievement (0.471, 1.111) in life science subjects, but all other subjects showed below-average academic achievement. In particular, subjects such as physics, chemistry, earth science, etc. showed the lowest average of academic achievement. Earth science class students showed above-average academic achievement (0.386, 0.798) in Earth science subjects alone. Statistically significant differences in all subjects according to R&E activity through Scheffé post-test ($p < .001$) appeared. Therefore, it indicates that R&E activities based on students' subject preferences and learning experiences greatly affect the academic achievement of science high school subjects.

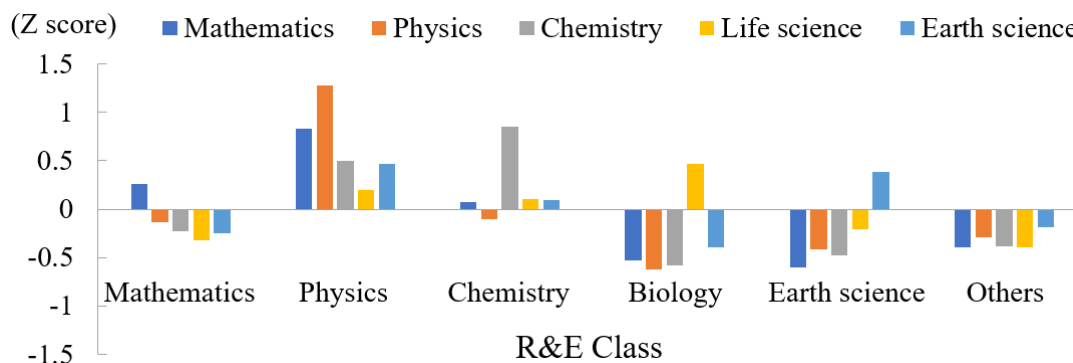


Figure 1. Standard Z score of mathematics and science subjects academic achievement according to R&E activity

3.2. Correlation analysis and factor analysis of academic achievement in mathematics and science

The correlation between each subject was analyzed based on the academic achievement of 296 first-year G

science high school students over three years (2009, 2013, 2018). The Pearson correlation coefficient between each academic achievement by year is shown in Table 2.

Mathematics subjects showed the highest positive correlation (.635~.802) with physics subjects in each year, followed by chemistry (.498~.746), earth science (.332~.519), and life science (.232~.481). Physics subjects showed the highest positive correlation with mathematics, followed by chemistry (.475~.773), earth science (.549~.608), and life science (.227~.544) in order. Chemistry subjects showed relatively high positive correlations with all subjects, including mathematics, physics, earth science (.498~.666), and life science (.361~.636). Life science subjects showed a relatively high correlation between earth science (.575~.729) and chemistry but a relatively low correlation between mathematics and physics subjects.

It can be seen that these results are in good agreement with the results of previous studies on science high school students [12]. Recent results showed that the positive correlation between all subjects increased, and the correlation coefficient deviation between subjects decreased. However, there was no significant change between physics and earth science subjects, and chemistry showed a higher correlation than other subjects, but the change over the year was insignificant.

Table 2. Pearson correlation coefficient between mathematics and science subjects academic achievement

Year		Mathematics	Physics	Chemistry	Life Science	Earth Science
2009	Mathematics	1				
	Physics	.635**	1			
	Chemistry	.498**	.475**	1		
	Life Science	.232*	.227*	.361**	1	
	Earth Science	.332**	.549**	.498**	.575**	1
2013	Mathematics	1				
	Physics	.697**	1			
	Chemistry	.535**	.578**	1		
	Life Science	.383**	.400**	.537**	1	
	Earth Science	.420**	.558**	.586**	.614**	1
2018	Mathematics	1				
	Physics	.802**	1			
	Chemistry	.746**	.773**	1		
	Life Science	.481**	.544**	.636**	1	
	Earth Science	.519**	.608**	.666**	.729**	1

** p < .01; * p < .05

The correlation between mathematics and science subjects confirmed through correlation analysis showed a significant correlation between all subjects, but subjects with differences in correlation coefficients between subjects were noted. Through exploratory factor analysis, we tried to analyze the factors in mathematics and science academic achievement and study the meaning of each factor.

In order to find out the characteristics of students' mathematical and scientific academic achievement, an exploratory factor analysis of mathematical and scientific academic achievement was conducted for students who entered G science high school in 2018. In addition, in order to increase the reliability and validity of the

analysis results, factor analysis was simultaneously performed on two science high schools (G science high school: 103 students, C science high school: 81 students) in the same area in 2018, and the results are compared and shown in Table 3. Values with factor loading values of less than 0.5 were omitted.

As a result of factor analysis of mathematics and science academic achievement, the total variance of G science high school students was 86.35%, and the total variance of C science high school students was 87.94%. Therefore, in comparing the two groups, most of the information from the five subjects can be seen as having sufficient validity with two factors. Subjects with high and similar factor loading values in one factor can be treated as a common variable in academic achievement. In factor 1 (F1), mathematics and physics subjects showed factor loading values of 0.867 to 0.918, and in factor 2 (F2), life science and earth science subjects showed factor loading values of 0.818 to 0.913. Based on the results of previous studies, we tried to divide mathematics and science subjects into two factors corresponding to "logical-mathematics intelligence" and "natural understanding intelligence" through the academic achievement of science high school students [14].

Therefore, F1 was divided into logic-mathematics factors, and F2 was divided into natural understanding factors. Chemistry subjects showed factor loading values of 0.5 or more in both F1 and F2, which appeared in the middle area of logical-mathematical and natural understanding.

As shown by correlation analysis, in factor analysis, mathematics is grouped into the same factors as physics subjects, and life science includes earth science subjects in the same factors. On the other hand, chemistry subjects were found to be included in both factors.

Table 3. Results of exploratory factor analysis of math-science subjects in two Science High Schools

Subjects	G Science High School			C Science High School		
	F1	F2	Com	F1	F2	Com
Mathematics	.918		.893	.892		.898
Physics	.867		.873	.869		.889
Chemistry	.755	.510	.831	.687	.572	.799
Biology		.895	.873		.913	.921
Geology		.850	.848		.818	.890
Eigenvalue	2.362	1.956		2.332	2.065	
%of Variance	47.23	39.12		46.64	41.30	
Cumulative %	47.23	86.35		46.64	87.94	

Extraction method: Principal Component Analysis; Factor Rotation: Varimax; Com=Communality

3.3. Characteristic factors of academic achievement in mathematics and science according to the characteristics of R&E activity areas

A factor analysis of students' achievement in mathematics and science subjects according to the R&E activity area was performed, and the results are shown in Table 4. As a result of the analysis, the subjects tied to the main factor (F1) were different depending on the R&E activity. Mathematics class students were found to be 46.13% of the total variance in the "natural understanding" subject group, and physics and biology classes students were also found to be "natural understanding" factors, accounting for 43.28% and 42.38% of the total variance, respectively. However, chemistry and earth science students were identified as the main factors in the "logical-mathematical" factor, accounting for 42.62% and 42.24% of the total variance.

Through factor loading values, the characteristics of academic achievement by R&E activity class were found to be "logical-mathematical" factors in mathematics and physics, "natural understanding" factors in life science and earth science, and chemistry subjects in the middle area. In the academic achievement of students in mathematics, physics, and biology classes, only earth science and life science subjects were found to be 'natural understanding' factors, while in the academic achievement of students in chemistry and earth science classes, only earth science and life science subjects were found to be 'natural understanding.'

Table 4. Exploratory factor analysis of mathematics and science subjects academic achievement in R&E Class

Subjects	R&E Class										
	Mathematics		Physics		Biology		Chemistry		Earth science		
	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	
Mathematics		.935		.927		.893	.811			.834	
Physics		.745		.673		.763	.780			.870	
Chemistry	.677	.520	.612	.617	.635	.638	.791			.808	
Life science	.890		.928		.899			.837			.906
Earth science	.903		.818		.820			.912			.875
Eigenvalue	2.307	1.793	2.164	1.857	2.119	2.029	2.131	1.849	2.112	1.725	
% of Variance	46.13	35.86	43.28	37.14	42.38	40.57	42.62	36.98	42.24	34.50	
Cumulative %	46.13	81.99	43.28	80.42	42.38	82.95	42.62	79.60	42.24	76.74	

Extraction method: Principal Component Analysis; Factor Rotation: Varimax; F1=Factor 1; F2=Factor 2

Students were divided into four factor groups based on the average score of the 'logical-mathematical' factor (F1) and the 'natural understanding' factor (F2) obtained through the achievement factor analysis of 296 G science high schools, and the distribution ratio of students in each group by R&E class is shown in Figure 2.

Mathematics class students were primarily distributed in group B, and showed rarely distribution in group C. Physics class students were concentrated and distributed in groups A and B, and showed rarely distribution in groups C and D. Chemistry class students are widely distributed in group A. Biology class students were concentrated in group C, and showed rarely distribution in groups A and B. The students of the earth science class were concentrated and distributed in group C. The distribution characteristics of physics and biology classes were clearly distinguished. group A (51.8%) and group B (42.9%), which students in physics class primarily distribute, are groups with high logical-mathematical scores, and group C (52.8%), which students often see in biology class, is a group with low logical-mathematical score and high natural understanding score.

In particular, the difference in the distribution of students according to each R&E activity area in groups B and C is remarkable. In group B, there are many math and physics students, and there are few biology class students. In group C, there were many students from the biology and earth science classes, and fewer from the mathematics and physics classes.

Cross-analysis was performed between achievement levels according to the R&E activity area, and it was confirmed that there was a statistically significant ($p < .001$) difference between the achievement factor groups according to the R&E activity area through χ^2 values and p values.

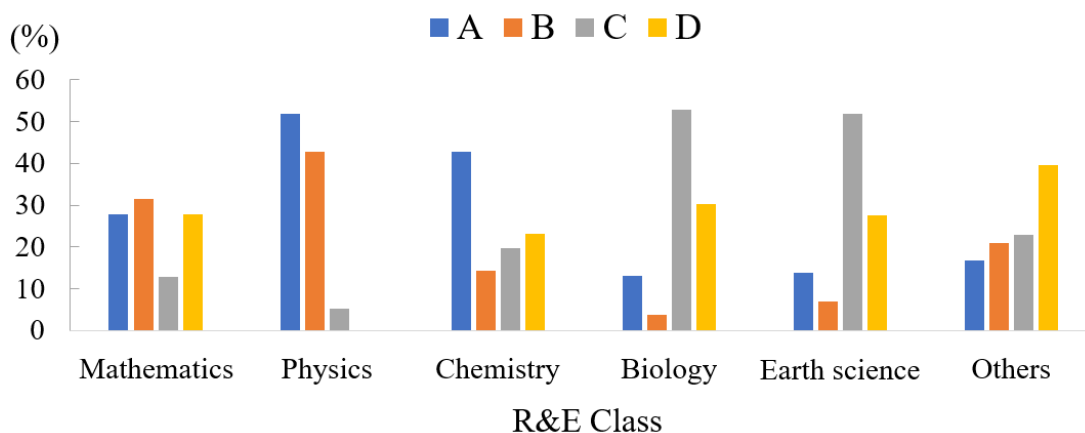


Figure 2. The distribution ratio of math and science subject factors is according to the R&E activity group. (A group: Group with both F1 and F2 scores higher than the average, B group: Group with high F1 and low F2, C group: Group with low F1 and high F2, D group: Group with both F1 and F2 scores lower than the average)

4. CONCLUSIONS

For the purpose of improving students' self-directed research skills such as scientific inquiry, creative problem solving, cultivation of research attitudes as scientists, etc., it operates six task research (R&E) programs classes in mathematics, physics, chemistry, biology, earth science & information, and convergence science. Students will be learning in the R&E program class they want. Students not only focus on their preferred task research (R&E) program activities but also achieve the purpose of task research with much effort. Therefore, students will change their academic achievement in the subject with much effort in their preferred task research (R&E). The characteristics of task research (R&E) activities affect academic achievement in mathematics and science subjects through correlation analysis and factor analysis of academic achievement, and characteristic factors of academic achievement appeared.

The relationship between science high school students' R&E activity area and mathematics and science subject achievement was analyzed through cross-analysis and one-way ANOVA, and the results of examining the subject's characteristics through correlation analysis and factor analysis are as follows.

First, the experience of task research (R&E) activities of science high school students was closely related to the academic achievement of related subjects. It is believed that science high school students choose the field of task research (R&E) activities according to their interests or talents, and the experience of R&E activities effectively fosters the ability required for learning in each subject.

Second, as a result of the correlation analysis between mathematics and science academic achievement, it was divided into two subject groups: mathematics and physics, life science, and earth science, and chemistry was located in the center. In addition, the correlation coefficient between mathematics and science subjects was high in recent results.

Third, as a result of factor analysis in mathematics and science academic achievement, it was possible to obtain "logical-mathematical" factors represented by mathematics and physics subjects and "natural understanding" factors represented by life science and earth science subjects.

Fourth, in factor analysis in mathematics and science academic achievement according to the area of R&E activity, there were differences in subjects grouped into the same factors as subjects, which are the main factors, depending on the area of task research (R&E). Natural understanding was the factor that had a more significant

influence on academic achievement in the mathematics, physics, and life sciences classes, while logical-mathematical was the factor in the chemistry and earth science classes.

Fifth, there was a distinct difference in the distribution of students in the factor group of academic achievement by R&E activity area. Physics class students were concentrated in the group with excellent logical-mathematical ability, and biology class students were widely distributed in the group with excellent natural understanding ability.

The results of this study are expected to greatly contribute to the selection of topics, inquiry performance, conclusion drawing, inquiry capacity, etc., of science high school task research (R&E) in the future.

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