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A Semantic Network Analysis on the Recognition of STEAM by Middle School Students in South Korea

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ABSTRACT
The purpose of this study is to investigate how much Korean students recognize STEAM (Science, Technology, Engineering, the Arts, and Mathematics) and to find out what keywords they associate with it and what the relationships among keywords mean. This study has surveyed 1,009 middle school students by using the purposive sampling method. In order to achieve the goal of this study, we have developed a questionnaire in consultation with survey research experts. The questionnaire asks each student to write down three words that come to his or her mind in each area of study: S/T/E/A/M. The survey was conducted during the period between July and September, 2016, and the results were collected directly from the target groups. For data analysis, KrKwic was used for selecting top 30 keywords, and Ucinet6.0 was employed to obtain meaningful relationships among keywords in the whole network. Then we built and visualized a network by using Netdraw. In this study the contents of analysis include the frequency of keywords, the network degree centralization index. The results of this study can be summarized as follows: First, the words students associate with science are "experiment, chemistry, physics, scientist, biology, life, etc." Second, the words students associate with technology are "machine, home economics, robot, science, , invention, technician, etc." Third, the words students associate with engineering are "machine, technology, robot, computer, mechanical engineering, science, college of engineering, engineer, etc." Fourth, the words students associate with the arts are "art, music, painting, beauty, dancing, song, dance in Korean, etc." Fifth, the words students associate with math are "calculation, function, numbers, difficulty, equation, formula, etc." Sixth, With regard to STEAM, middle school students recognize science as experiment, technology and engineering as machine, arts as art, math as calculation. Seventh, Each network of STEAM turns out to be a complicated one. It is difficult to find a meaningful creation of images due to their lack of learning experience in combined knowledge. This explains the need of learning experience in the STEAM programs. The fact that all of middle school students consider STEAM difficult supports this explanation.

Keywords: middle school students, STEAM, recognition, network, semantic network analysis, network degree centralization index

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Contribution of this paper to the literature

- The purpose of this study is to describe how Korean middle schoolers conceive interdisciplinary conversion.
- The study shows that students recognize 'Science as an experiment', 'Technology and Engineering as a machine', 'Arts as the fine arts', 'Math as a calculation'.
- In this study, networks links one another through teachers, which means the role of a teacher in STEM, interdisciplinary conversion, is vital.

INTRODUCTION

We call our contemporary society 'liquid modernity', which means a fission-fusion society. We call it so because knowledge fusion and technology fusion, which break the barriers of monolithic education, such as one discipline, one technology, and one curriculum, are creating more unique and more competitive results. Recently, Korean education places greater emphasis on combined and fusion education in order to produce creatively gifted individuals equipped with humanistic imagination and scientific creativity by making them immersed in the foundational knowledge about humanity, sociology, science, and technology (Ministry of Education, 2015). The beginning of this approach can be traced back both to "The Reinforcement of STEAM Education at the Elementary, Middle, and High School Levels" from one of the 2010 Six Great Projects of the Ministry of Education called "Nurturing Gifted Students in Science and Technology," and to "The Second Foundation Plan for Nurturing and Supporting Gifted Students in Science and Technology (2011-2015)." Since then, Korea Foundation for the Advancement of Science and Creativity has been leading consistent efforts to vitalize the Science, Technology, Engineering, Arts, and Math (STEAM) programs. In addition, STEAM education in Korea is closely related to STEM programs in the U.S., a term made by the National Science Foundation (NSF) to stand for Science, Technology, Engineering, and Math in the 1990s. Since then, the term has been widely used to mean an integrated approach to science, technology, engineering, and math in the field of education (Hong, K.H., 2012). One of the reasons for the need of the arts in STEAM in Korea, which is born as a strategy, can be found in our efforts to motivate creative thinking and innovative ideas in science through imagination, creativity, communication, and sensibility, which are usually obtained from arts education (Noh, S.W. and Ahn, D.S., 2012). Another reason is that we are trying to equip certain individuals with abilities to put together even artistic sensibilities in the field of science and technology, so that they will be leaders of this age of fusion.

Our attempt as a fundamental and interactive approach is considered a desirable and timely research in that it investigates how middle school students think about and have relationships with science, technology, engineering, arts, and math as elements of knowledge fusion in school education.

Therefore, this study will survey the general outline of STEAM education, investigate specific images Korean middle school students have regarding each subject of S/T/E/A/M, and analyze both the keywords and the relationships among keywords recognized through a semantic network analysis.

Based on the results of this analysis, we will investigate the application of STEAM education and explore ways to improve the effectiveness of STEAM education for middle school students.

THEORETICAL BACKGROUND

The Outline of STEAM in Korea

As mentioned above, STEAM in Korea is a term coined by combining the initials of science, technology, engineering, arts, and mathematics, which first appeared officially in a report to the Ministry of Education, Science, and Technology in 2011 (Choi, Y.H., Lee, E.S., Kim, D.H., 2013). The background of the execution of STEAM education can be found in the fact that the level of Korean students' confidence, delight, voluntariness, and interest in math and science is among the lowest, lagging far behind that of their overseas peers, and that there is a marked tendency, as a consequence, for them to avoid entering into these fields of studies. Since national competitiveness

in current society of science and technology is affected by how quickly we adapt to an age of rapid innovation, especially in the areas of science, technology, and engineering, the educators in these fields are now making every effort to change their curricula by fusing and integrating diverse disciplines in order to meet the need of change for the future society (Park, H.J., 2014). In this situation, the objective of STEAM is to nurture those with integrated creativity, who will lead our future development of science and technology, by restructuring the curriculum of science-technology-engineering-math with strong emphasis on core capacities, so called 4C (Creativity, Communication, Convergence, and Caring) and by combining diverse courses together and grafting them with artistic skills. In this regard, the Korean version of STEAM works as a policy implemented to provide an instrument to solve the problems involved in science and technology education in Korea, give our students dreams and visions, and enhance their interest and understanding in these fields (Ministry of Education, Science, and Technology, 2010).

According to Baek, Y.S. et al.(2012), a class formation for STEAM is composed of three big components as demonstrated Emotional Touch, Creative Design, and Content Integration—and has a structure with a virtuous circle that motivates students, nurtures them to be able to solve problems comprehensively, and gives them a sense of challenge. That is to say, STEAM means a shift from the perspective of "what to teach" to "what experience to give," so that it places emphasis on the content, design, and emotional convergence.

In addition, the study of STEAM also has moved from the study of STEM-related overseas literature at its initial stage now to curriculum-centered STEAM content research which deals with the effects of its application to students. It has been confirmed that most of STEAM researches conclude that the application of STEAM in education is effective in directing students to positive changes like improving creativity, problem solving skills, self-directed learning ability, integrated consciousness, and students' interest and confidence in science and technology (Kim, J.W., 2016).

Semantic Network Analysis

A semantic network analysis is a method of analyzing the content of the communication message by making it a target of text network analysis. It is a kind of method that encodes the relationships among keywords, construct a network among related keywords, and analyze the result of the findings (Doefel & Connaughton, 2009; Yang, S.D., 2013). Content analysis through a semantic network analysis not only helps us comprehend the frequency of keywords, but also demonstrates visually the relationships among keywords. This gives us a chance to see at a glance the important concepts, as well as the relationships and their strengths among concepts (Suh, J.I., 2015).

There is a limitation in a traditional method of content analysis in that a significant difference among researchers in classifying and interpreting data could occur (Kim, S.Y., Kim D.W., & Choi, M.I., 2013; Park, H.W. & Leydesdorff, 2004). As a way of supplementing this limitation, a semantic network analysis can find a regulation, which used to be hidden in the information or unrevealed visually, by performing a job of transferring the information into data (Jung, Y.I., 2005). In other words, it focuses not only on the combination of each individual word, but also on how keywords are combined in a specific way, where they are located after being combined in a particular way, and what kind of structure they have. Then it finds out a specific meaning, while an analysis category from the data (a conceptual grouping) is naturally formed in the process (Park. H.W. & Leydesdorff, 2004; Wasserman & Faust, 1994). Especially, visualization in this method makes it possible to comprehend the outline of the entire, gigantic, and complicated data in a short time, which makes analysis more meaningful.

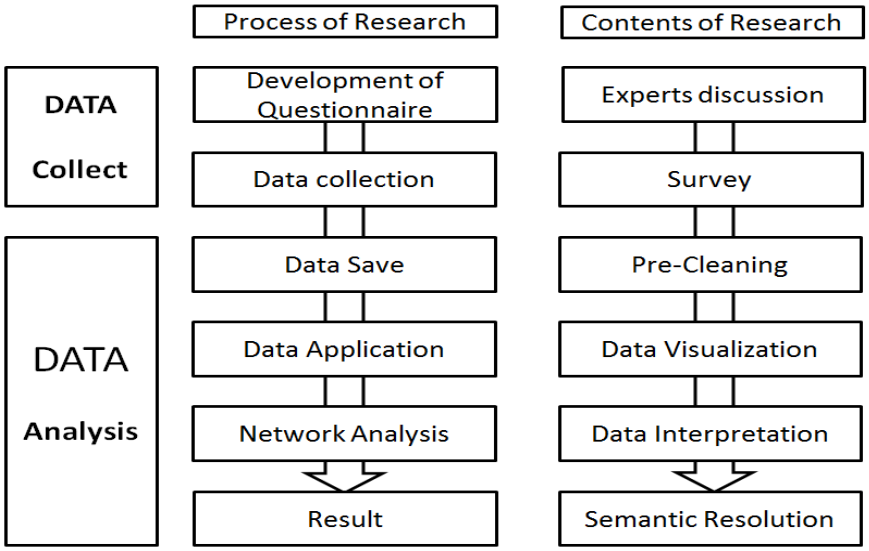

Figure 1. A process of research

Table 1. General characteristics of the survey respondents

Sex	1st Grade	2nd Grade	3rd Grade	Total
Female	154	159	133	446
Male	202	177	159	538
No Answer	7	11	7	25
Total	363	347	299	1009

METHODS

Process of Research

This research has been performed separately in two stages, data collecting and data analyzing. At the data collecting stage, a questionnaire was developed and a survey was conducted based on the developed questionnaire. The data analyzing stage was composed of coding of the questionnaire, a process of purifying terminologies and transferring data for analysis, visualizing and interpreting the network, and finding out the meaning of the result. The **Figure 1** above is graphically provided for your reference.

In order to achieve the goal of this study, we have developed a questionnaire in consultation with survey research experts. The questionnaire asks each student to write down three words that come to his or her mind in each area of subject: science (S), technology (T), engineering (E), the arts (A), and math (M).

Data Collecting

The survey was conducted among middle school students in the Daejeon area in South Korea during the period between July and September, 2016, and the results were collected directly from the target groups. The results show that a total number of 1,009 students participated in the survey.

Analyzing of the Networks

For the analysis of the research, we used MS Excel 2016, KrKwic, Ucinet 6.0 and Netdraw. By using Excel 2016, we did data Pre-Cleaning in order to combine keywords with the same meaning into a common keyword, and by using KrKwic, we selected the top 30 keywords, and by using Ucinet 6.0, a link filtering was employed to

Table 2. Division of centrality

Division	Degree centrality
Measuring Method	Measuring by the number of directly connected neighboring nodes
Characteristics	•Proper to measure the direct effectiveness •The more neighboring nodes are connected, the higher degree centrality becomes.

Sah, I.R. (2016). Excerpted and summarized from the analysis of social network using NetMiner

obtain meaningful relationships among keywords in the whole network. Then we built and visualized a network by using Netdraw. The content of analysis includes the degree of keyword frequency and the analysis of the centralization index. The analysis of the centralization index figures out which node is the most important one, and how much the network is concentrated in the minor nodes. This study tries to figure out degree centrality.

Interpreting of the Networks

In the network between keywords, the keyword is node, and the connection between nodes is represented by Link. Such a network can grasp the overall shape at a glance. In this case, the thickness of the line means that the degree of connection between the keywords is high, and the size of the node means a large intersection point between the sub-structures.

FINDINGS

Middle School Students' Recognition about Science and Their Recognition Network

With regard to the term, science, a total number of 533 image words occurred to middle school students participating in the survey. The following is the list of top 30 keywords among their responses in the survey. (Refer to **Table 3**)

"Experiment" is the most frequently occurring word to middle school students with regard to the term, science. As scientific activities, they recognize "experiment, research, exploration, observation," and as a subject of science, they recognize "chemistry, physics, biology, the universe, technology, earth science, robot, math" in order of frequency. As a job in the field of science, they recognize "scientist, teacher, and researcher" in order of frequency. As for feelings about science, they consider it "difficult and interesting," while they place the value of practical use of science in the "future and development."

For the top 30 keywords, the semantic network was analyzed. As a result, the network's degree centrality turned out to be 0.2412, making it a complex network. The network is presented as follows. (Refer to **Figure 2**)

Table 3. Image words occurring to mind about science

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Keywords	experiment	chemistry	physics	scientist	biology	life	difficulty	research	universe	technology
Degree	366	257	175	108	92	61	58	58	49	47
Rank	11	12	13	14	15	16	17	18	19	20
Keywords	earth science	exploration	teacher	earth	Invention	robot	earth	observation	math	cell
Degree	47	41	37	37	35	34	34	29	28	28
Rank	21	22	23	24	25	26	27	28	29	30
Keywords	future	beaker	fun	development	plant	chemical symbol	machine	researcher	exam	research institute
Degree	28	27	23	23	22	20	18	17	16	16

(Mean of Degree centrality: 0.008)

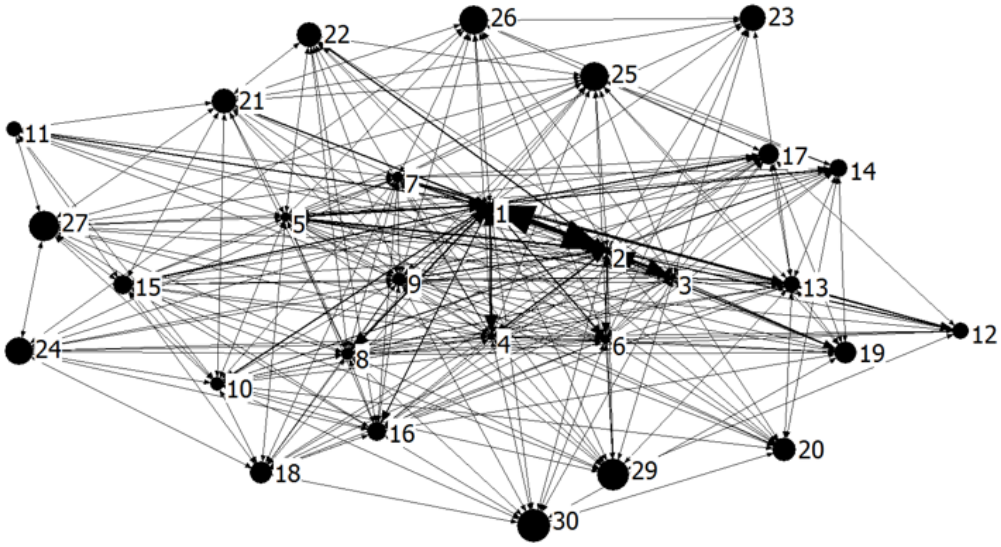

Figure 2. Middle school students' recognition network about science (The numbers of network are rank keywords of **Table 3**)

Middle School Students' Recognition about Technology and their Recognition Network

With regard to the term, technology, a total number of 661 image words occurred to middle school students participating in the survey. The following is the list of top 30 keywords among their responses in the survey (Refer to **Table 4**).

"Machine" is the most frequently occurring word to middle school students with regard to the term, technology. As products of technology, they recognize "a robot, computer, car, and smartphone" in order of frequency, and as technology-related subjects, they identify "home economics, science, and engineering" in order of frequency. It is assumed that the term, called "home economics," appears in the list because students are taught "technology and home economics" as two subjects in the area of technology education. "Development, future, and convenience" appear in the list as values of technology, while "invention, architecture, construction, manufacturing, skillfulness, patent, research, and producing" are recognized as technical activities.

Table 4. Image words occurring to mind about technology

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Keyword	machine	home economics	robot	science	invention	technician	teacher	computer	development	architecture
Degree	216	147	113	66	65	63	57	53	52	51
Rank	11	12	13	14	15	16	17	18	19	20
Keyword	factory	technology education + home economics	making	engineering	construction	car	difficulty	manufacturing	electricity	skillful-ness
Degree	45	44	42	34	33	32	30	29	28	24
Rank	21	22	23	24	25	26	27	28	29	30
Keyword	convenience	ability	future	tool	making	patent	scamper	science + technology	technology	research
Degree	24	23	23	18	18	17	17	17	17	16

(Mean of Degree centrality: 0.012)

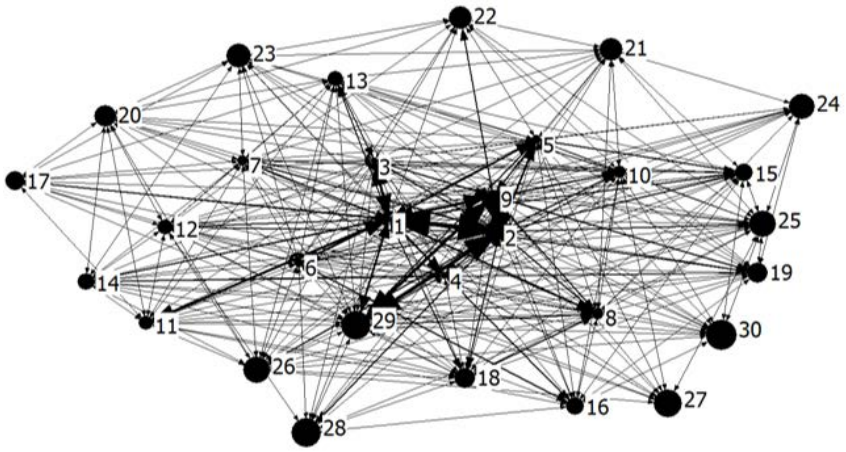

Figure 3. Middle school students' recognition network about technology (The numbers of network are rank keywords of **Table 4**)

For the top 30 keywords, the semantic network was analyzed. As a result, the network's degree centrality turned out to be 0.2001, making it a complex network and it appeared to be relatively less complex than science. The network is presented as follows. (Refer to **Figure 3**)

Middle School Students' Recognition about Engineering and their Recognition Network

With regard to the term, engineering, a total number of 536 image words occurred to middle school students participating in the survey. The following is the list of top 30 keywords among their responses in the survey. (Refer to **Table 5**)

"Machine" is the most frequently occurring word to middle school students with regard to the term, engineering. As for the products of engineering, their answers include a "robot, computer, and car" in order of frequency, and as engineering-related subjects, they identify "technology education, mechanical engineering, science, electronics, electricity, math, life, biotechnology, and architecture." As other images about engineering, they recognize "college of engineering, engineer in Korean, factory, design, engineer, and fields of science." This can be interpreted that students have two kinds of images about engineering: one is an image of research by an engineer through college of engineering in the fields of science; and another is an image of technician working in the factory. In addition, engineering appears to them "difficult and complicated." As engineering activities, they choose "design, invention, research, making, and assembly."

One thing unusual in this survey is that "coeducation" is included in their recognition network because coeducation has the same phonetic sound as engineering in Korean, though its Chinese character is different.

Table 5. Image words occurring to mind about engineering

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Keyword	machine	technology	robot	computer	mechanical engineer	science	college of engineering	difficulty	electronics	engineer in Korean
Degree	382	170	132	108	81	77	53	49	44	42
Rank	11	12	13	14	15	16	17	18	19	20
Keyword	electricity	math	car	life	factory	coeducation	biotechnology	design	architecture	engineer
Degree	37	36	35	33	31	30	27	26	23	23
Rank	21	22	23	24	25	26	27	28	29	30
Keyword	robotics	invention	research	electronic engineering	chemistry	complexity	fields of science	making	assembly	university
Degree	23	22	20	20	19	19	17	16	16	14

(Mean of Degree centrality: 0.019)

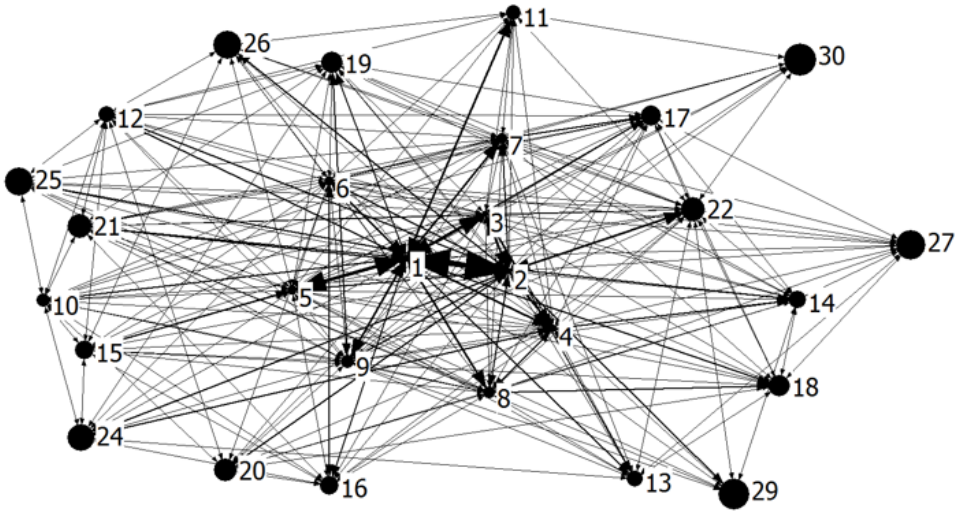

Figure 4. Middle school students' recognition network about engineering (The numbers of network are rank keywords of **Table 5**)

For the top 30 keywords, the semantic network was analyzed. As a result, the network's degree centrality turned out to be 0.2028, making it a complex network so that its level appeared to be similar to that of science. The network is presented as follows. (Refer to **Figure 4**)

Middle School Students' Recognition about Arts and their Recognition Network

With regard to the term, arts, a total number of 486 image words occurred to middle school students participating in the survey. The following is the list of top 30 keywords among their responses in the survey. (Refer to **Table 6**)

"Art" is the most frequently occurring word to middle school students' mind with regard to the term, arts. As arts-related majors, they recognize "art, music, dance, physical education, sculpture, ballet, and movie," and as artistic activities, they include "painting, dancing, singing, creative writing, performance, making, and creating." As for occupational clusters which are related to arts, "a painter and an artist" stand out as the most representative ones. And the rest of the words related to arts include "art gallery, Picasso, brush, creativity, and culture."

It is quite remarkable that words like creativeness and creativity are highly ranked in the list, making students' recognition about art distinguishable from their recognition about science, technology, engineering, or math.

Table 6. Image words occurring to students about arts

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Keyword	art	music	painting	beauty	dancing	dance in Korean	work of art	physical	painter	singing
Degree	548	380	260	103	80	64	52	51	51	48
Rank	11	12	13	14	15	16	17	18	19	20
Keyword	carving	pigment	art gallery	Picasso	sculptor	creativeness	performance	ballet	creativity	design
Degree	40	32	31	24	23	23	21	19	19	18
Rank	21	22	23	24	25	26	27	28	29	30
Keyword	brush	artist	culture	musical instrument	art, music, physical	making	interesting	movie	creating	difficulty
Degree	18	18	17	17	17	15	16	15	15	14

(Mean of Degree centrality: 0.026)

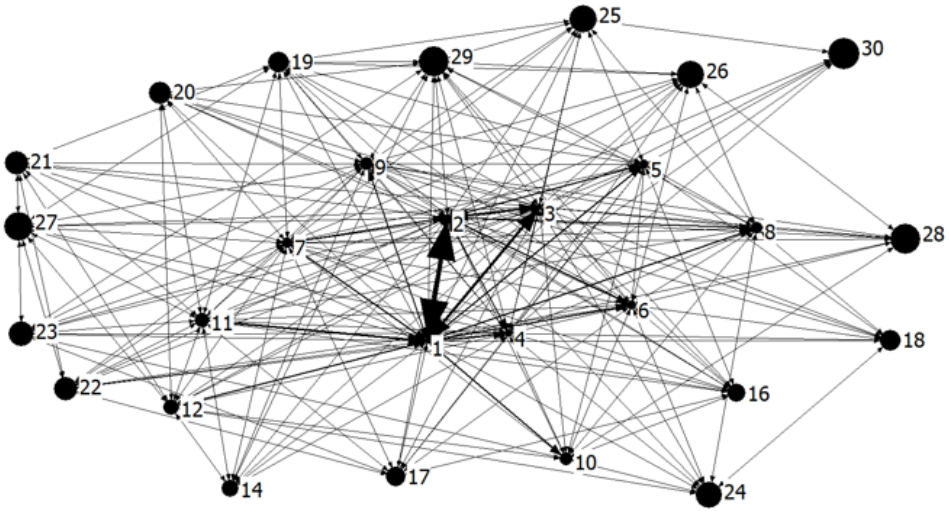

Figure 5. Middle school students' recognition network about arts (The numbers of network are rank keywords of **Table 6**)

For the top 30 keywords, the semantic network was analyzed. As a result, the network's degree centrality turned out to be 0.1157 which means a complex network. The network is presented as follows. (Refer to **Figure 5**)

Middle School Students' Recognition about Math and their Recognition Network

With regard to math, a total number of 492 image words occurred to middle school students participating in the survey. The following is the list of top 30 keywords among their responses in the survey. (Refer to **Table 7**)

"Calculation" is the most frequently occurring word to middle school students with regard to the term, math. Their recognition about math is composed of certain words related to solving mathematical problems like "calculation, function, numbers, equation, formula, calculation steps, unknown quantity, Pythagoras, addition, arithmetic, graph, and subtraction."

On the top of their recognition list about math, there is no recognition related to other fields of study like science, technology, engineering, or arts. As math-related activities, they recognize "problem solving and application."

For the top 30 keywords, the semantic network was analyzed. As a result, the network's degree centrality turned out to be 0.1674, which means a complex network with its level similar to that of arts. The network is presented as follows. (Refer to **Figure 6**)

Table 7. Image words occurring to mind about math

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Keyword	calculation	function	numbers	equation	difficulty	formula	figure	teacher	calculation steps	addition
Degree	208	206	156	151	150	132	68	56	47	46
Rank	11	12	13	14	15	16	17	18	19	20
Keyword	calculus	complexity	mathematician	Pythagoras	unknown quantity	graph	problem	arithmetic	exam	subtraction
Degree	45	43	42	41	41	35	35	35	32	31
Rank	21	22	23	24	25	26	27	28	29	30
Keyword	multiplication	symbol	problem solving	hakwon	x value	linear equation	calculation	annoying	application	numbers
Degree	27	27	27	25	24	24	21	21	21	20

(Mean of Degree centrality: 0.021)

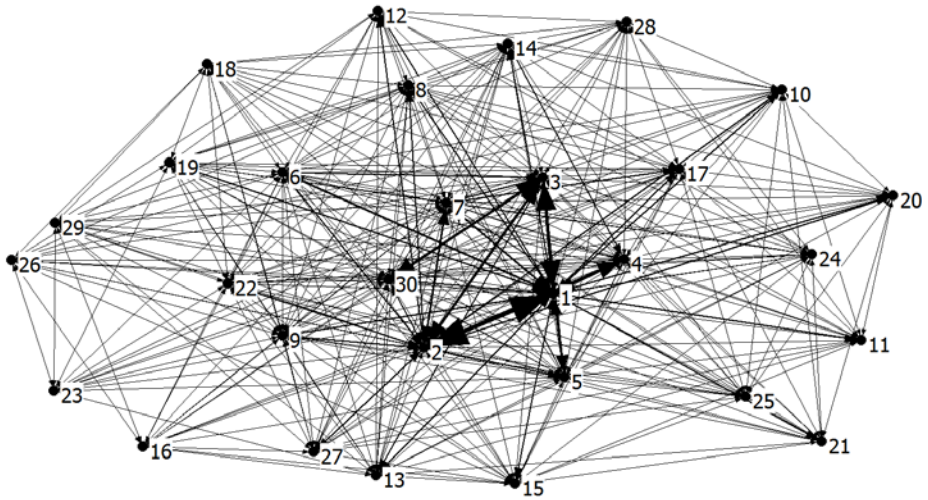

Figure 6. Middle school students' recognition network about math (The numbers of network are rank keywords of **Table 7**)

Comprehensive Recognition of Keywords about STEAM

When we put together those keywords from science, technology, engineering, arts, and math, and present them as a network, the result is as follows. (Refer to **Figure 7**)

The following is a chart presented based on the common elements of the whole network (Refer to **Table 8**)

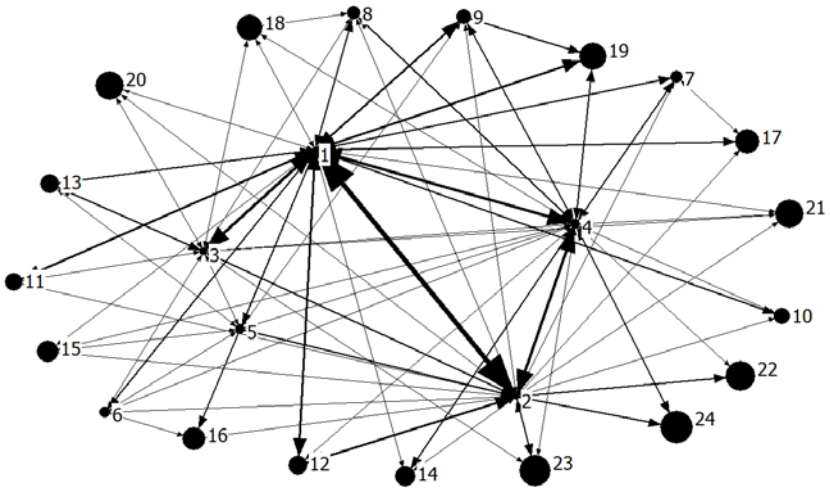

Figure 7. Middle school students' recognition network about S-T-E-A-M (The numbers of network are rank keywords of **Table 8**)

Table 8. Image words occurring to mind about S-T-E-A-M

Classification			Science	Technology	Engineering	Arts	Math
Key word	1	Science		○	○		
	2	Technology	○		○		
	3	Math	○		○		
	4	Engineering					
	5	Arts					
	6	Difficulty	○	○	○	○	○
	7	Machine	○	○	○		
	8	Robot	○	○	○		
	9	Making		○	○	○	
	10	Invention	○	○	○		
	11	Teacher	○	○	○		○
	12	Research	○		○		
	13	Fun	○			○	○
	14	Architecture		○	○		
	15	Factory		○	○		
	16	Future					
	17	Development					
	18	Complex			○		○
	19	Life	○		○		
	20	Exam	○				
	21	Fields of Science			○		○
	22	Car		○	○		
	23	Electricity		○	○		
	24	Computer		○	○		

Middle school students recognized that Science and Technology were linked to each other, and Science was conceptually related to Mathematics and Engineering. Technology has been linked to science and engineering. In particular, the conceptual link between Science, Technology and Engineering has been linked to key words such as 'machine, robot, invention'. The keyword 'teacher' appears to work in a way that conceptually connects mathematics to science - technology - engineering.

In other words, it is difficult for middle school students to associate mathematics with science-engineering-technology on their own, so it is necessary to provide a method of linking mathematics based on the professionalism of the teacher. The way of linking art is possible through 'production and enjoyment'. For this reason, it seems that STEM education, which is difficult to understand, may be transformed into enjoyable activities by utilizing art.

IN SUMMARY

First, there is a common recognition among middle school students that STEAM is difficult to them all; Second, a network of technology-engineering-arts is formed through the element of making; Third, some elements in the common network of science-technology-engineering turn out to be "robot, invention, machine, teacher, and difficulty." Fourth, technology and engineering are recognized very similarly, while some elements in the common network of technology-engineering turn out to be "science, robot, invention, machine, factory, car, computer, architecture, electricity, teacher, making, difficulty." Fifth, by the element of teacher, a network of science-technology-engineering-math (STEM) is formed.

CONCLUSION

The ultimate purpose of this study is to investigate individual images that Korean middle school students have regarding each subject of S/T/E/A/M, and analyze the recognized keywords and the relationships among keywords through a semantic network analysis. The conclusion of this study is as follows:

1. With regard to STEAM, middle school students recognize science as experiment, technology and engineering as machine, arts as art, math as calculation. The result shows that they recognize each subject of STEAM through their learning experience at the level of middle school students. Especially, the fact that they recognize both engineering and technology as machine, arts as art, and math as calculation means they form their concept at a general level.
2. Each network of STEAM turns out to be a complicated one. It is difficult to find a meaningful creation of images due to their lack of learning experience in combined knowledge. This explains the need of learning experience in the STEAM programs. The fact that all of middle school students consider STEAM difficult supports this explanation.
3. Technology, engineering, and arts are formed in a common network through an element of "making," while science-technology-engineering are formed in a common network through "robot, invention, and machine." This means that they get certain images about combined network with technology, engineering, arts, and science. We conclude that significant issues like making as a method, and common topics like robot and invention, have been drawn from this study.
4. Technology and engineering appear to be so similar to each other that dividing them into two subjects could cause students some confusion.
5. By the element of "teacher," STEM is found to be connected within itself, which makes the role of the teacher important in STEM.

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