Teachers' perception on Computational Thinking in Science Practices

Se young Park, Young Jeon

Abstract**—**Scientific literacy in science education can be improved through the process of scientific knowledge formation and a series of inquiry process, such as having a question to a phenomenon and forming a problem, designing an experiment by analyzing models for the problem solving, and preparing evidences with the experiment results and discussing to find the answer. These activities were organized and proposed as eight practices of Science and Engineering by NRC. Among eight science practices, 5th practice is related to computational thinking, and the term of computational thinking is also uprising concepts in computer education. Yet, these two concepts are relatively new to many teachers. Thus, in this research, the authors attempted to find relationship between 5th science practice and nine computational thinking concepts. The survey result found that science teachers and computer teachers were sharing similar visions in terms of relevancy of computational thinking concepts on 5th science practice.

Keywords**—** Science education, ICT in education, Computational Thinking, 8 Practices of Science and Engineering education.

I. Introduction

THERE are two important pillars of 21st century industry: Science & engineering and information communication technology (ICT). Firstly science and engineering industry is developing rapidly and it has become important global issue to produce talented human resources in relevant area. Science allows people to better understand the world and expand the imagination. Business and the economy are growing and human race can evolve through science. In the world of global competition based on ICT, Science education becomes more important than ever. Today, despite high unemployment rate, companies and academics are experiencing difficulties in recruiting adequate candidates and this phenomenon is more noticeable in science and technology field including ICT.

The scientific literacy is the ability to understand the concepts and principles of science and technology, so learners can actually apply them in the actual situation. Thus, science education in the 21st century has emphasized that students should be able to cultivate scientific literacy through science curriculum in their school age [1],[2]. American association for the advancement of science (AAAS) constructed 'Project 2061' and proposed 'Benchmarks for science literacy' by categorizing the components of scientific literacy and it is expected the scientific knowledge learned in school age can be actually applied in students' real life situation [3].

Furthermore, national research council (NRC) of USA also focused on integrative thinking skills to explore the existing elements of the inquiry in science education and reset the science education standards by refining and extending the previous one. One of the results is eight science practices in science education for inquiry process and the movement toward strengthening science education continues.

Meanwhile, as mentioned earlier, Information and ICT industry including software industry expands its territory widely and applied in everywhere of our lives, which is applicable in science and engineering industry and also in schools. Most schools are already equipped with various ICT infrastructures and connected to Internet for educational purpose. As ICT environments are prepared and improved in school, the demands for using computers for educational purposes and computer education itself are continuously growing. Along with the trends, using ICT resources for education purpose is also required increasingly. Students can develop inquiry ability and creativity during the problem solving process with computers and the abundant resources which computers provides. While the notion of computer application in education has been changing students' activities in schools, students need to be able to structure their own knowledge and proactively solve the problem in schools and their real lives. Computers can be placed in the central role in this process with computational thinking (CT) by allowing students to use various functions of technology; from complex computing and data representation to real life like simulation.

The inclusion of computational skills is gradually deepened and it is not just considered as substitutional tools but central learning resource in education scene. Also, computational thinking concepts are introduced in many educational guidelines for many subjects including science. For instance, STEM or STEAM education has been stressed as a global education trends. And the reason for this trend is the traditional division of education system cannot teach students to be prepared for the rapidly changing society. So developing talents with integrative education of science, technology and engineering sectors is required to enhance national competitiveness [4]. In Science and technology, engineering education, progress has been active in various interdisciplinary fusions to satisfy the needs for preparing talents who lead future society and industry.

The integrative efforts also can be found in eight science practices of NRC. Among eight practices, computational thinking is specifically mentioned in 5th practice, so computational thinking can be used in the science learning

S. Y. Park is with the Korea Research Institute for Vocational Education & Training, Sejong-si, 30147 Republic of Korea (Tel:+82444153946; e-mail:seyoung.park.0108@gmail.com).

Y. Jeon is with the Korea Research Institute for Vocational Education & Training, Sejong-si, 30147 Republic of Korea (Tel:+82444153937; e-mail:dortus09@gmail.com).

and inquiry process. However, since both computational thinking concepts and science practices are relatively new to many educators. Teachers in school are struggling for applying every new policies and curriculums to class. Teachers need expertise of each subject curriculum and also need general understanding of further information to apply newly updated approaches. Meanwhile there are less available guidelines for combining these two new concepts to deliver the actual lesson. Thus, this research analyzed the linkage between 5th practice of NRC's eight science practices and computational thinking's nine concepts, to suggest the appropriate application of computational thinking concepts in science practices.

II. LITERATURE REVIEW

A. Science education in 21st Century

As the importance of inquiry process is highlighted, recent science education has been concerned that inquiry lessons are only focused on the superficial function of inquiry, but not in actual performance of inquiry [5], [6]. Inquiry activities only focusing on the inquiry functions do not offer students opportunities to set their own problem, design their problem solving model, and discuss with fellow students for better experiment and result [7],[8]. Thus, students cannot actually understand the process of forming scientific knowledge through inquiry, but acquire the procedure of inquiry which can cause students to have misconceptions that inquiry process has determined procedures or framework as they have only experienced in schools [5], [6].

Reflecting this scientific educational scene, NRC (2012) focused in improving concepts of inquiry process and integrative thinking skills and reset the scientific education standards by refining and extending the previous inquiry elements and proposed eight scientific practices by developing scientific inquiry of previous national science education standards [1]; 'Asking questions and defining problems', 'Developing and using models', 'Planning and carrying out investigations', 'Analyzing and interpreting data,' 'Using mathematics and computational thinking', 'Constructing explanations and designing solutions', 'Engaging in argument from evidence', 'Obtaining, evaluating, and communicating Information'(see <Table II>).

<Table II. 8 Practices of Science [8]>

Practice	Definition
1.Asking Questions and Defining Problems	To formulating, refining and evaluating empirically testable questions and design problems using models and simulations.
2.Developing and Using Models	To predict and show relationships among variables between systems and their components in the natural and designed worlds.
3.Planning and carrying Out Investigations	To include investigations that provides evidence for and test conceptual, mathematical, physical, and empirical models.
4.Analyzing and Interpreting Data	To introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
5.Using Mathematics and Computational Thinking	To using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
6.Constructing Explanations and Designing Solutions	To explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories
7.Engaging in Argument from Evidence	To using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
8.Obtaining, Evaluating, and Communicating Information	To evaluating the validity and reliability of the claims, methods, and designs.

A. Computational Thinking (CT) education in 21st Century

The approach toward computers in Education has been gradually developed and intensified. Computers are not only considered as useful tools for education delivery but important resources for thinking process in the 21st century. In 2006, Wing (2006) introduced the concept of computational thinking (CT) and according to her, CT is the basic thinking ability for everyone lives in knowledge-based information society and it requires students to understand basic concepts of computer science and problem solving mechanism based on computer science[9]. On the other hand, CSTA (Computer Science Teachers Association) in USA announced K-12 Computer Science Standards and proposed CT should be applied to every subject of schools, which is the wide arrange of thinking process. According to them, students can learn the capacity and the limitation of computing during the progress of constructing new knowledge and problem solving strategies by learning and using CT [10]. <Table I> shows the nine specific concepts of CT which can describe various learners' thinking strategies during their learning situation.

These concepts are not necessarily applied only for computer education class and encouraged to be combined with various subject matters [11]. Computational thinking is a cognitive ability which can be utilized for problem solving, system design, and generating new knowledge. It also refers to the ability to understand the influence and limitation of computing in the current society. Therefore, computational thinking allows students to improve conceptual and analytical thinking and to solve complex problems with choosing appropriate tools and strategies in virtual/real life situation [12], [13].

<Table I. 9 Concepts of Computational Thinking [10] >

Concept	Definition

Data Collection	The process of gathering appropriate information
Data Analysis	Making sense of data, finding patterns, and drawing conclusions
Data Representation	Depicting and organizing data in appropriate graphs, charts, words, or images
Problem Decomposition	Breaking down tasks into smaller, manageable parts
Abstraction	Reducing complexity to define main idea
Algorithms & Procedures	Series of ordered steps taken to solve a problem or achieve some end.
Automation	Having computers or machines do repetitive or tedious tasks.
Simulation	Representation or model of a process. Simulation also involves running experiments using models.
Parallelization	Organize resources to simultaneously carry out tasks to reach a common goal.

B. *Linkage between CT education and Science education*

The emphasis on using computers in education starts with the introduction of ICT infrastructure and resources in schools. Computers allow providing abundant resources in various channels, thus students can learn in more real-life like situation with multi-sensory stimulation. While, due to the nature of scientific knowledge, it is more effective to use audiovisual ICT media to acquire knowledge elements of science rather than describing with texts [14]. Topics in science subject cover wide scope from microscopic particles to macroscopic cosmos. Moreover, required learning elements vary from abstract concepts that require thinking process to concrete topics can be physically experiment. Thus, to guide students can understand these scientific concepts more effectively, a variety of audio-visual materials and computers have been actively utilized in recent years. Also efforts to improve teaching and learning lead to the extensive use and collaboration of computers in various subjects along with the intensive development of computer education. Computers have become the tools not only for teaching various concepts with multisensory resources, but also it is extended to offer web-based learning and scientific exploration with databases and simulation programs [15].

Computational science can be a good example. Computational science is the field of science dealing with the problems of scientific theory using computers for calculation. It mainly studies and understands research objects by using computers for interpreting mathematical models. By using the web platform or SW programs, it is possible to perform complex scientific calculation more effectively [16]. Through this, students do not need to spend much time on manually calculating insignificant details and focus on actual scientific knowledge acquisition. Also students can design and perform a variety of their own calculations, and students can learn the practical knowledge when they enter the science industries. These days, because students make good use of internet, it is possible to participate in computational science even they are not having intensive computer knowledge. Thus, this information should be delivered from class, and as <Table III> shows computational thinking is already mentioned as NRC 5th Practice; Using Mathematics and Computational thinking, so students can practice CT for science inquiry and problem solving activities [17].

<Table III. Sub practices of ‘Using Mathematics and Computational Thinking, (NRC, 2013)>

Practice title	Detailed Practices
Using Mathematics and Computational Thinking	1. Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system 2. Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations 3. Apply techniques of algebra and functions to represent and solve scientific and engineering problems 4. Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model “makes sense” by comparing the outcomes with what is known about the real world 5. Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

However, the question arises that how science teachers can apply CTs in their classroom activities. When the teachers are confronted new concepts, they may find it difficult to apply it into the lessons. It becomes more serious issues in current study, because, CT combination with science practices requires a general understanding of both concepts which are considered as derived from different subjects. Therefore, the current study aimed to propose the relevant CT concepts on 5th science practice. At first, survey was conducted with science and computer teachers to find relationship between CT concepts and 5th science practice. In addition, interview was delivered with respondents, so to draw a possible explanation of the suggested CT concepts per sub categories of 5th science practice.

III. RESEARCH

A. *Method*

A survey was conducted with 10 science teachers and 10 computer teachers to understand the current perception of teachers on CT concepts’ application of 5th science practice. Participants’ age range was from 25 to 45 and they were selected among in-service teachers or graduate students who majored science education or computer education. Thus, it was make sure that science teachers understood the science practices and computer teachers understood the CT concepts in advance. To proceed the survey, they received in-detail explanation five sub-practices of 5th science practice of and nine CT concepts, so they can decide the relevance of each items. In survey, respondents were asked to check on most relevant CT concepts per each sub-practice and after the survey; interview was followed to find the possible reasons for the survey result.

B. Result

<Table IV. Relevant CT concepts on 5th SP>

	Total	Science teachers	Computer teachers
Sub practice 1	8(17.6%), 6 (16.2%), 2 (14.9%)	6, 8 (18.4%), 3 (15.8%)	2, 4, 8 (16.7%)
Sub practice 2	6 (21.9%), 3 (20.3%), 2, 8 (10.9%)	3, 6 (20.6%), 7, 8 (11.8%)	6 (23.3%), 3 (20.0%), 4 (16.7)
Sub practice 3	4, 6 (17.9%) 2, 3 (16.4%)	2, 3 (17.6 %), 4, 6 (14.7%)	4, 6 (21.2%), 3, 5 (15.2 %)
Sub practice 4	8(27.9%), 6 (16.4%), 7(11.5%)	8 (25.8%), 6, 7 (16.1%)	8(30%), 6 (16.7%), 4, 5 (13.3%)
Sub practice 5	3 (19.4%), 6, 2 (16.1%)	3, 5 (18.8%), 6 (15.6%)	2, 3 (20.0%), 6 (16.7%)

1. Data collection, 2.Data analysis, 3.Data representation, 4. Problem decomposition, 5.Abstraction, 6.Algorithms & Procedures, 7.Automation, 8.Simulation, 9.Parallelization

It was found that the most of computer teachers and science teachers were sharing similar visions. In practice 1, simulation (17.6%) was selected as a most relevant concept to ‘create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system’ and it was followed by algorithms and procedures (16.2%) and data analysis (14.9%). While science teachers thought data representation (15.8%) is important, computer teachers thought problem decomposition (16.7%) is also important concept. In practice 2, algorithms and procedures (21.9%) and data representation (20.3%) were chosen as important concepts and both science and computer teachers listed these two concepts as most relevant concepts to use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations (practice 2).

Science and computer teachers showed similar opinions on practice 3 (Apply techniques of algebra and functions to represent and solve scientific and engineering problems) and practice 4 (Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model “makes sense” by comparing the outcomes with what is known about the real world). Problem decomposition and algorithms & Procedures (17.9%) were both ranked as the most relevant concepts in practice 3. Simulation (27.9%), algorithms & procedures (16.4%) and automation (11.5%) were chosen for the practice 4.

Lastly, data representation (19.4%), algorithms and procedures, data analysis (16.1%) were listed as the most relevant concepts which are very similar result with computer teachers’ opinion for the practice 5 (Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.). Meanwhile, science teachers answered that Abstraction (18.8%) is more relevant than data analysis (12.5%).

IV. Discussion

Science teachers need to be prepared so that they can build a lesson plan contains a variety of inquiry activities and scientific practice [18]. However some teachers are not sufficiently adapted to the newly introduced curriculum, or do not understand the nature of scientific inquiry and these teachers may find it difficult to plan the inquiry classes. Science teachers should be guided to fully understand the eight science practices so they can actually apply the practices in their science classes. CT educations and its concepts also have been highlighted continuously. Combined with the emphasis of SW education, the demands and interests are focused on computational thinking. However, practical classroom activities are nothing near to be satisfied status. Teachers should not remain at the low level of ICT and CT application in their classes, and they should be able to attempt to lead students can experience high level of actual CT application process for problem solving. Thus, it should be accompanied by teachers’ awareness-raising about the ICT and CT application for education. Teachers are having struggle in the flood of too much materials and tasks in their workplace. It can be overwhelming tasks for teachers to be always ready to apply new discoveries and curriculums. However, if it is involved the provision of necessary materials and proper guidance, then the science education and CT education can be activate as it is expected.

The survey results were discussed in detail with follow up interview with teachers and according to the result of survey and interview. Firstly, there were some quite straight forward explanations of the responses. Such as in practice 1, the reason of choosing simulation as relevant concepts was the term of simulation was specifically mentioned in the practice definition. So without further consideration teachers chose simulation, yet both computer teachers and science teachers were not sure about what kind of simulation they expect. Secondly, algorithms & procedures were appeared in every sub practices, and it was because one of the important goals of conducting science practice is improving students’ problem solving ability; to understand the target object, to develop the appropriate tasks and to place the tasks as a series of step. Lastly, another interesting part of the result was teachers’ percept of ‘automation’ between science and computer teachers. in practice 4, science teachers selected automation as a relevant concept since they focused more on the automatic calculation function of computer. In total result, science teachers’ choice of automation as a relevant concept was 15.4% (4th), yet computer teachers’ response was stayed in 5.7% (7th). Science teachers expected more on the function of computer devices while they were matching the relevance concepts. In the meantime computer teachers’ considered automation will be used in every practice, so they focused more on the preliminary process to make computer runs automatically.

Also with the interviews revealed as following information.

Science teachers found that understanding the details of CT concepts helped them to develop new ideas to perform better lesson activities, and they became more confident to include 5th practice in their classes. Computer teachers could understand 5th practice for science education and they also found new ideas to deliver CT lessons by using science practices. Additionally, computer teachers answered they became more willing to cooperate with science teachers for assisting technical issues and collaboration practice in science class.

V. CONCLUSION

The current studies analyzed the relevance between 5th practice of eight science practices and CT's nine concepts to provide the guidelines of application of 5th science practice in the classroom. After proper understanding of contents, science teachers and computer teachers answered similarly; thus it can be safe to propose most relevant CT concepts for sub practices of 5th SP as following; Practice 1 : simulation, algorithms & procedures, data analysis; Practice 2: algorithms & procedures, data representation, data analysis; Practice 3: problem decomposition, algorithms & procedures, data analysis, data representation; Practice 4: simulation, algorithms & procedures, automation; Practice 5: data representation, algorithms & procedures, data analysis. Moreover it was also found that after matching activity between 5th science practice and CT concepts during the survey, teachers could understand the relevance between those two concepts and develop new ideas for their classes. Also, it was suggested that CT concepts can be applied into various stages with numerous formats and it was depends on teachers' lesson goals

This research was finished at providing basic relationship between 5th SP and CT concepts, and revealing the possible relation of teachers' understanding of eight science practices and CT concepts and their willingness to combine the two contents. For further research, it can be studied that relationship between the science teachers' understanding on eight science practices and CT concepts and the actual level of science inquiry class delivery.

APPENDIX

<Appendix 1. CT-5th SP – Teachers' response- total>

S&E / CT	Sub-P 1	Sub-P 2	Sub-P 3	Sub-P 4	Sub-P 5	Tot.
Data Collection	7 (9.5)	3 (4.7)	3 (4.5)	3 (4.9)	2 (3.2)	18 (5.5)
Data Analysis	11 (14.9)	7 (10.9)	11 (16.4)	5 (8.2)	10 (16.1)	44 (13.4)
Data Represen -tation	9 (12.2)	13 (20.3)	11 (16.4)	3 (4.9)	12 (19.4)	48 (14.6)
Problem Decompo -sition	9 (12.2)	8 (12.5)	12 (17.9)	6 (9.8)	7 (11.3)	42 (12.8)
Abstraction	7 (9.5)	5 (7.8)	8 (11.9)	5 (8.2)	8 (12.9)	33 (10.1)
Algorithms & Procedures	12 (16.2)	14 (21.9)	12 (17.9)	10 (16.4)	10 (16.1)	58 (17.7)
Automation	4 (5.4)	4 (6.3)	5 (7.5)	7 (11.5)	8 (12.9)	28 (8.5)
Simulation	13 (17.6)	7 (10.9)	5 (7.5)	17 (27.9)	4 (6.5)	46 (14.0)
Paralleliza -tion	2 (2.7)	3 (4.7)	0 (0.0)	5 (8.2)	1 (1.6)	11 (3.4)
Total	74 (100)	64 (100)	67 (100)	61 (100)	62 (100)	328 (100)

<Appendix 2. CT-5th SP – Science teachers' response>

S&E / CT	Sub-P 1	Sub-P 2	Sub-P 3	Sub-P 4	Sub-P 5	Tot.
Data Collection	5 (13.2)	2 (5.9)	2 (5.9)	2 (6.5)	1 (3.1)	13 (7.7)
Data Analysis	5 (13.2)	3 (5.8)	6 (17.6)	3 (9.7)	4 (12.5)	23 (13.6)
Data Represen -tation	6 (15.8)	7 (20.6)	6 (17.6)	2 (6.5)	6 (18.8)	30 (17.8)
Problem Decompo -sition	3 (7.9)	3 (8.8)	5 (14.7)	2 (6.5)	4 (12.5)	21 (12.4)
Abstraction	2 (5.3)	2 (5.9)	3 (8.8)	1 (3.2)	6 (18.8)	19 (11.2)
Algorithms & Procedures	7 (18.4)	7 (20.6)	5 (14.7)	5 (16.1)	5 (15.6)	35 (20.7)
Automation	2 (5.3)	4 (11.8)	4 (11.8)	5 (16.1)	4 (12.5)	26 (15.4)
Simulation	7 (18.4)	4 (11.8)	3 (8.8)	9 (25.8)	1 (3.1)	32 (18.9)
Paralleliza -tion	1 (2.6)	2 (5.9)	0 (0.0)	2 (9.7)	1 (3.1)	15 (8.9)
Total	38 (100)	34 (100)	34 (100)	31 (100)	32 (100)	169 (100)

<Appendix 3. CT-5th SP – Computer teachers' response>

S&E / CT	Sub-P 1	Sub-P 2	Sub-P 3	Sub-P 4	Sub-P 5	Tot.
Data Collection	2 (5.6)	1 (3.3)	1 (3.0)	1 (3.3)	1 (3.3)	6 (3.8)
Data Analysis	6 (16.7)	4 (13.3)	5 (15.2)	2 (6.7)	6 (20.0)	23 (14.5)
Data Represen -tation	3 (8.3)	6 (20.0)	5 (15.2)	1 (3.3)	6 (20.0)	21 (13.2)
Problem Decompo -sition	6 (16.7)	5 (16.7)	7 (21.2)	4 (13.3)	3 (10.0)	25 (15.7)
Abstraction	5 (13.9)	3 (10.0)	5 (15.2)	4 (13.3)	2 (6.7)	19 (11.9)
Algorithms & Procedures	5 (13.9)	7 (23.3)	7 (21.2)	5 (16.7)	5 (16.7)	29 (18.2)
Automation	2 (5.6)	0 (0.0)	1 (3.0)	2 (6.7)	4 (13.3)	9 (5.7)
Simulation	6 (16.7)	3 (10.0)	2 (6.1)	9 (30.0)	3 (10.0)	23 (14.5)
Paralleliza -tion	1 (2.8)	1 (3.3)	0 (0.0)	2 (6.7)	0 (0.0)	4 (2.5)
Total	36 (100)	30 (100)	33 (100)	30 (100)	30 (100)	159 (100)

REFERENCES

[1] National Research Council. (2000). *Inquiry and the national science education standard,* Washington, DC: National Academy Press.

[2] J. Osborne, " Science Education for the Twenty First Century,". Eurasia Journal of Mathematics, Science & Technology Education. vol. 3, no.3, pp. 173-184, 2007.

[3] C. Merrill and J. Daughty, "STEM education and leadership: A mathematics and science partnership approach,". Journal of Technology Education. vol. 21, no. 2, pp. 21-34, 2010.

[4] American Association for the Advancement of Science [AAAS](1993). *Benchmarks for science literacy,* New York: Oxford University Press.

[5] R. Driver, P. Newton, and J. Osborne, "Establishing the norms of scientific argumentation in classroom ," Studies in Science Education. vol. 84, no. 3, pp. 287-312, 2000.

[6] National Research Council. (2012). *A Framework for K-12 science education: practices, crosscutting concepts, and core ideas,* Washington, DC: National Academy Press.

[7] Duschl. R. A., & Osborne, J. "Supporting and promoting argumentation discourse in science education," Studies in Science Education. vol.38, no.1, pp. 39-72, 2002.

[8] National Research Council. (2013). *The Next Generation Science standard,*. Washington, DC: National Academy Press

[9] M. J. Wing, "Computational thinking," Communications of the ACM. vol. 19, no. 3, pp. 33-35, 2006.

[10] (CSTA and ISTE, 2011).

[11] S. Gulwani, "Example-based learning in computer-aided stem education," Communications of the ACM, vol.57, no.8, pp. 70-80, 2014.

[12] Whitman, L. E., & Witherspoon, T. L. "Using legos to interest high school students and improve k12 stem education," Proceedings of the 33rd Annual Frontiers in Education. pp. 6-10, 2003

[13] X. Chen, "Students Who Study Science, Technology, Engineering, and Mathematics (STEM) in Postsecondary Education. Stats in Brief", NCES. National Center for Education Statistics, 2009.

[14] M. Mistler-Jackson and N. B. Songer, "Student Motivation and Internet Technology: Are you Students Empowered to Learn Science? ," Journal of Research in Science Teaching. vol. 37, no. 5, pp. 459-479, 2000.

[15] J. Hargis, "Can students learn science using the internet? ," Journal of Research on Computing in Education. vol.33, no.4, pp. 475-487, 2001.

[16] B. Y. Ahn, J. S. Ruth Lee, K. W. Cho, "Web-based Practice Education Supporting System for Computational Chemistry," The journal of Korean institute for practical engineering education. vol. 3, no. 2, pp. 18-26, 2011.

[17] Y. Jeon, "Analysis of inquiry sctivities in high school chemistry Ⅱ textbooks for the 2009 revised science curriculum: 8 practices of science", Master degree dissertation, Graduation school of education, Ewha womans university.

[18] Y. Li, X. Chen and G. Kulm, "Mathematics teachers' practices and thinking in lesson plan development: A case of teaching fraction division," ZDM. vol. 41, no. 6, pp. 717-731, 2009R. Driver, P. Newton, and J. Osborne, "Establishing the norms of scientific argumentation in classroom ," Studies in Science Education. vol. 84, no. 3, pp. 287-312, 2000.

Park, Se young is a research at the Korea Research Institute for Vocational Education & Training and a Ph.D, candidate at the Department of Computer Education, Korea National University of Education, Chungbuk 28173, Korea. (Tel:+82444153946; e-mail:seyoung.park.0108@gmail.com).