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Defining Science Core Competency in the 2015 revised Science Curriculum and Exploring its Application into STEAM program

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Abstract: The purpose of the study was to define five science core competencies introduced in the 2015 revised science curriculum with each component and practical indicators into the frame. Science teachers on site could use it in teaching and developing science program to equip students with the competencies to creatively solve problems which is the aim of science education in the 21st century. To develop this frame, we contacted 10 experienced science educators and collected the data through a questionnaire. We coded all responses and categorized into the components and practical indicators of each competency which were all compared with those from well-known theories in order to validate. We then contacted other 35 science educators again to construct the validity to fill out the survey of Likert scale. The finalized science core competency included 19 components in total with practical indicators that can be observable and measurable in the classroom. This frame was used to see how it fits into a STEAM program. The finding was that two different topics of the STEAM program displayed the different description of science core competency usage, which could be used as the prescription of the competency as to whether or not it is more promoted in science class.

Keywords: science core competency, 2015 revised science curriculum, creative problem solvers, STEAM

Introduction

The purpose of science education has been scientific literacy, which is defined as follows; ability to make decision of right or wrong about social scientific issues which people face from daily lives (NRC, 2000; Park, 2010). For this purpose, students are taught in getting more scientific knowledge to understand the issue, they learn how to carry out experimentation if needed and how to make claims with evidences from the experimentation to be logical in science, in addition, students must learn to quit their claims if they are against to ethics, morality, and environmental issues at the end (Choi et al., 2011; MOE, 2015). This is what scientific literacy is and students must learn the mentioned aspects above by doing science at schools as well as out of schools. For sure, many researches have released of how to promote students' scientific literacy in science teaching and learning as inquiry in their classroom (Crawford, 2000; Gormally et al., 2009; Lee, 1997; Park, 2006; Schwartz et al., 2009).

However, the goal of science education in the 21st century is beyond scientific literacy what we perceive at present in that not only students need to have abilities to make decision if SSI (social scientific issue) is right or wrong, but also students need to have abilities to apply their learnt concepts/knowledge to solve the problem issued from their community (NRC, 2013; Park & Hwang, 2017). Students must be equipped with abilities making them survive in the 21st century, 'the flood of information', where the amount of knowledge has grown enormously and knowledge has become a key means of production. Rather than simply accumulating the knowledge learned, it emphasizes practical ability to effectively solve the actual problem situation based on the basic knowledge and personal experience. Park & Park

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(2018) also supported this statement in that students need different thinking skills in doing science as problem solvers; student form scientific concepts through scientific thinking and they apply those concepts through computational thinking. Therefore, it is pivotal for students to be equipped with some skills to be problem solvers; this is the new extended definition of scientific literacy for the 21st century. Now, how can we make students equipped with those skills necessary as creative problem solvers?

In the knowledge-based society, the term 'competency' is becoming a new social concern. Knowledge-based society demands more ability to synthesize and analyze such knowledge and creativity to create new knowledge, rather than simply accepting or memorizing existing facts or knowledge. This ability has been frequently addressed in recent years in connection with the term 'competency' (So, 2007, 2009). In the 21st century, since knowledge-based society where information and knowledge are generated and distributed more rapidly than ever due to the rapid development and dissemination of information and communication technologies, it is necessary to differentiate more appropriate knowledge from inappropriate rather than possess a large amount of knowledge. By doing this, students can be equipped with abilities, which we call 'competency', to create useful knowledge and information in life (Cho and Yoon, 2014; OECD, 2006; Park et al., 2014).

For general competencies necessary for Korean in the future society, Lee et al (2008) selected 10 different competencies from the view of school education, vocational world, and lifelong learning society; creativity, problem solving ability, communication skill, information processing skill, interpersonal skill, self-management skill, basic learning skills, civic consciousness, international society culture and career development ability. PISA (2006) also illustrated core competencies in science education as follows; students need to have abilities, first, to reframe the question with argumentation in science, learn new knowledge, explain natural phenomena, and understand science with evidence to apply them; second, to understand the feature of science as the type of knowledge and inquiry done by human; third, to perceive how science and technology influence our physical, intellectual, and cultural environment; lastly to take attitude to get involved in argumentation of social scientific issue as one of citizen in the community. The trial of having core competencies in education explicitly has been made. First, MOE (2015) summarized the core competencies with each definition, covering all subjects (Table 1) in education; self-management, knowledge information processing, creative thinking, aesthetic emotional, communication, and community competency.

In the 2015 revised science curriculum, science core competency has been introduced to make scientific literacy more practical for the purpose of preparing students to be creative problem solvers in the 21st

Table 1. A summary of core competency and its implications (Ministry of Education, 2015)

Core competency	Definition
Self-management competency	Ability to live self-directly with self-identity and self-confidence as well as with basic skills and qualities necessary for his/her life and career
Knowledge information processing competency	Ability to process and utilize knowledge and information from various resources to solve problems reasonably
Creative thinking competency	Ability to create new things by combining and utilizing knowledge, skills and experiences of various special fields based on broad basic knowledge
Aesthetic Emotional competency	Aesthetic emotional capacity to discover and enjoy the meaning and value of life based on empathic understanding and cultural sensitivity of human
Communication competency	Ability to effectively express thoughts and feelings in different situations, to listen to and respect the opinions of others
Community competency	Ability to actively participate in community development with the values and attitudes required of members of the region, country, and global community

century (MOE, 2015; Rychen & Salganik, 2003; Sanders, 2009). Students needs to be trained to be creative problem solvers by experience the following 5 competencies; scientific thinking, scientific inquiry, scientific problem solving, science communication, and science engagement and lifelong learning (Table 2). Students use scientific thinking competency when they need to develop their own claims on the basis of evidence collected from experimentation. Students also experience the process of forming new knowledge by framing question, collecting data, analyzing data, interpreting data, and concluding remarks for ethical products, which we call scientific inquiry. Students also find out the problem from the community to be solved with the use of engineering and technology. During all these processes, students learn how to communicate effectively with other different people in the community. Students learn all views which should be considered through communication. Students will be citizen who are engaging in science activity and lifelong learning.

However, the information of how to teach and learn science in the classroom to produce the creative problem solvers is not given in the classroom to produce the creative problem solvers now. There have been debates that this new curriculum has been revised without the process of social needs, social debates, and consensus on competencies without a year (Kwak, 2016; Lee, 2015). The revised science curriculum provided only 5 competencies with their definition only, without guideline or concrete component with indicators of each competency provided. Science teaches face another problem of how to teach students with the goal of new science education; equipping students with 5 science core competencies. For sure, there have been trials for

Table 2. Science Core Competency in curriculum (MOE, 2015)

core competency in science	Definition/Description
Scientific thinking	Thinking skills necessary to explore the relation between scientific evidences and claim It is necessary to explore the relationship between scientific claim and evidence. This is the ability to think reasonably and logically on the basis of scientific view about world and nature, the process of scientific knowledge, and scientific evidence and theory. It is also ability to criticize the process of argumentation and evidence and to produce new idea.
Scientific inquiry	Skills of producing new scientific knowledge or understanding its values in the process of collecting data, interpreting and evaluating them from experimentation, investigation and discussion for problem solving. This is the ability to collect, interpret, and evaluate evidence in a variety of ways, including experiments, investigation, and discussions, to gain new scientific knowledge or construct the meaning to solve scientific problems. Scientific inquiry requires the ability to integrate, apply, and utilize scientific inquiry skills and knowledge, and scientific thinking is its basis.
Scientific problem solving	Ability to solving individual or public problems with the use of scientific knowledge as well as scientific thinking It is the ability to solve personal or public problems using scientific knowledge and scientific thinking. To solve problems from daily life, It is necessary to think and use knowledge of scientific facts, principles, concepts related to problems in collecting, analyzing, evaluating, selecting, and organizing various information and data, Problem solving ability includes reflective thinking ability and rational decision making ability for problem solving process
Scientific communication	Ability to adjust between my position and others to improve the process and its products of scientific problem solving in the community It refers to the ability to argue his or her thoughts and to understand and adjust the thoughts of others in order to share and develop scientific problem-solving processes and results within the community. This is also ability to understand and present opinion about scientific and technological information through various types of media such as computer and audio-visual equipment. This is the ability to demonstrate argumentation based on evidence.
Scientific engagement and lifelong learning	Ability to make decision of SSI through scientific participation individually as one of community members with responsibility as well as reasons through the life-long education It refers to the ability to participate in the decision-making process with an interest in the social problems of science and technology and to continuously learn on its own to adapt to the new science and technology environment in order to act rationally and responsibly as a member of society.

MOE or research group in science education to re-define science core competency with concrete explanation even after 2015 revised science curriculum. However, there has not been certain guideline for teachers to use on site yet. In this study, the researchers would try to define each competency with concrete components and practical indicators so that teachers use them practically in science teaching for the purpose of science education, as the extended definition of scientific literacy.

In addition, the STEAM (Science, Technology, Engineering, Arts and Mathematics) education is very dominating teaching and learning context in science classroom recently to meet this goal of science education for the last decade. This STEAM education policy of Korea has roots in STEM education which spreads internationally. STEAM education is new context where how science is taught and learned to meet the goal of science education, preparing students with abilities to be creative problem solvers. But what kind of characteristics do creative problem solvers hold? How can we know that students are equipped with abilities to be creative problem solvers? Here, the researchers in this study would combine these two issues; first, 5 science core competencies are described as essential abilities as problem solvers in the 21st century in the 2015 revised science curriculum; second, STEAM has been employed in science education with the purpose of preparing students to be creative problem solvers also. In this study, the researchers will provide guideline with 5 science competencies assisting teachers to recognize what kinds of competency are included in the textbook or program, especially in STEAM program, and if they can teach those competencies on the basis of their clear understandings of each competency.

In this study, the researchers operationally define those 5 competencies introduced in newly revised science curriculum to be more practical for science teachers and science educators to employ them in developing textbooks or program and in teaching them in the one frame. This frame can be applicable in planning science lesson and evaluating them in the classroom as well as out of classroom. This frame will consist of each competency with a few components with practical indicators which are observable and measurable. The research questions will be as follows: (1) what components of each science core competency are possible; (2) what indicators can be possible in each component; (3) how this science core competency analyzing frame can be validated. The significance of this study is science teachers' expertise in teacher education as well as science curriculum from K to 12. Science teachers can use this frame for STEAM teaching also as planning as well as assessing tools to check if those 5 competencies are included in STEAM program.

Methodology

To develop the science core competency analyzing frame (SciCoCoAF), the researchers employed the following steps Fig. 1.

The 1st Empirical Data Collection and Coding

The researchers contacted 10 experienced science educators (science teachers at schools and science communicators at science museum and they had at least 5 years teaching experience with visitors as well as students) by purposive sampling. The researchers developed questionnaire including consent form, the purpose of this study, and 5 big questions of science core competencies. Each science core competency was provided with its definition only made by MOE (2015). Then participating science educators provided their own operational definitions for each competency with concrete examples/incidents. The researchers coded participants' responses to be categorized into a few components (3-4) in each competency with practical indicators. The researchers constructed the validity of coding process with other science educators (2 science educators) through discussion to be consensus in data analysis.

The 2nd Theoretical Data Collection

The coded categories were compared with theoretical

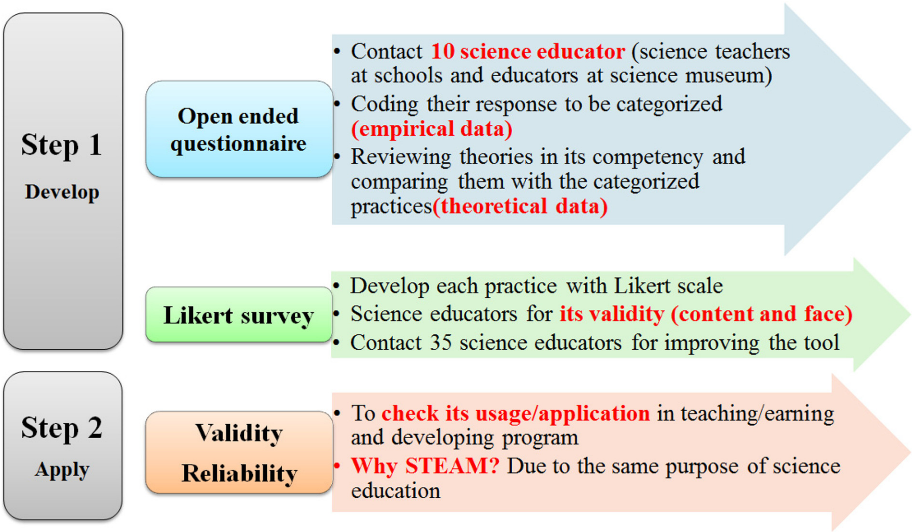

Fig. 1. The flow of methodology.

data in the 2nd process of data collection. The researchers, for example, compared 3 components of scientific thinking competency with the theories about scientific thinking from literature review. From the coding, there were 4 components of scientific thinking; logical, critical, creative, and rational thinking. The researcher, however, excluded “thinking rationally” after comparing with theories of scientific thought, since rational thinking was partially overlapped with the other three thinkings coded in the 1st process, empirical data. In this way, the researchers modified components and practical indicators of each science core competency. During this process, the researchers discussed with other two science educators to be consensus for content validity and its reliability.

The 3rd Data Collection through Survey by Likert Scale

The SciCoCoAF has been reformatted by Likert survey to be distributed to another 35 science educators so that they could check if each component in each science core competency with practical indicators was understandable. If not, respondents left some opinions in each cell provided so that the researchers used responses for the next modification. This process was how to construct face validity as well as content with its reliability at the same time. The below survey is original format used in this study. 35 respondents were supposed to check in each cell of each component if they would agree; if they would not agree, they were supposed to leave the opinions.

Science core competency	Component	√	Opinion
Scientific Thinking	Logical thinking		
	Critical thinking		
	Creative thinking		
Scientific Inquiry ability	Recognizing scientific problems		
	Collect data with various exploration		
	Analyzing collected data		
	Interpret the results and draw a conclusion		
Scientific problem-solving ability	Recognizing the scientific issues in daily life		
	Identifying the scientific factors relating to the problem		
	Reflective thinking		
	To present and implement a solution		

Scientific communication ability	Communicate in various ways Demonstrating Coordinate opinions Know how to use various media
Scientific engagement and lifelong learning ability	Recognizing community problem Interested in SSI or STS issues Learning voluntarily Understanding the science from daily life

Construct the Validity and Reliability

The completed SciCoCoAF has been employed into STEAM program to check its usage. First of all, the researchers tried to check what components of each competency were observable and measurable by applying this frame into STEAM program. After checking its application in two STEAM programs (for the validity in data collection, two STEAM programs has been selected in this study), the researchers each tried to describe what components and how much each science core competency could be included or not and compare the results to be discussed. This is how to construct frame's validity and reliability. The reason why STEAM program has been selected for checking frame's usage was that the purpose of equipping students with 5 science core competencies is the same of that of STEAM education; equipping students to be creative problem solvers. Each 10 lessons of climate change and water shortage STEAM program for the middle school level earlier developed by the researchers were used to see if the developed science core competency analyzing frame was applicable in STEAM program to construct the validity of the frame.

Results

The researchers collected the data from 10 participating science educators by the open question-naires first. Participants responded of how they defined in each science core competency on the basis of their practical experience on sites as well as theories. Then, those responses were coded by the researchers, then a few components were developed in each competency. Those components were compared with those of theories in literature review for the validity. The 2nd survey as the type of Likert was employed into another 35 science educators for checking the validity again. During this process, there was some modification in each component with its indicator. Finally the completed frame has been implemented into STEAM program to see its usage.

Develop components of each science core competency with practical indicators

10 participants from science education field (science teachers and science communicators who had at least 5 years of teaching experience) responded the questionnaire and five science competencies have been recognized by participants as follows. 10 participants in the 1st step provided all various personal experience, episode, and critical incidents describing scientific thinking with the help of its definition given in the survey. The researchers then read and re-read participants' responses (Table 3) to derive certain common indicators. Then those derived temporary components of each competency were compared with those derived from literature well known and defined by other authors theoretically. This is how to construct the validity. If there was mismatching between empirical data and theoretical one, the researchers discussed them to be modified to the final. Then the survey of Likert scale was employed to another 35 respondents to construct the validity again. The following is the example of how scientific thinking competency was defined through those steps mentioned above.

Scientific thinking competency: 10 participants responded with episode from their experience about

Table 3. Scientific thinking core competency (partial responses from participants in this study)

Definition By MOE		It is basic thinking skill to explore the relationship between scientific claims and evidence. It is the ability to reason logically based on scientific evidence and theory. It is also the ability to criticize reasoning processes and arguments as well as the ability to produce diverse and original ideas.
Your own definition and example	1	*To make the roller coaster by using beads, adjust the slope of each section so that the beads can reach to the end. In order to prevent the beads from stopping in the middle, there is a certain gradient in each section (checking if it is too severe without stopping in the middle), and consider the weight of each bead, gravity, inclination, centrifugal force,* ***finding out all possible Factors affecting the phenomenon***
	2	*Ability to think **logically and scientifically** in situations of everyday life*
	3	*Definition:* *A framework of **systematic and logical thinking** based on experience and evidence to recognize or solve problems/ phenomena* *Example* *Through his knowledge about granite, he recognizes the rocks as granite- by its appearance (**pattern, induction**), and thinking processes* *-Thinking process that envisions a way to get the most out of minimal cost and work to make a simple portable telescope.* *-Thinking process that conceives **a sequence of probable factors that may cause** drones broken*
	4	*-Lead them to **logically explain their claims** in the process of exploring and inferring process after **identifying the evidence** of continental drift and* *-Geological evidence (shoreline overlapped): I made students puzzle a map of the world as pieces,* *-Geological evidence (continuity of geologic structure): A coarse straw was inserted into two kinds of cakes (analogous to geology), and the residue of the cake remaining in the straw was checked to see which cake it was.* *-Biological evidence (distribution of fossil fossils): We shared opinions and presented biological fossils that cannot cross the sea.* *-Climatological evidence (glacial distribution and direction of movement): Illustrated in place of pictorial data.* *→ The above activities were organized and recorded so that **they could express their ideas.***
	5	*Scientific Thinking refers to a series of processes that begin with **"Why?" Where students have curiosity about natural phenomena**, and have their own logic and interpretation about phenomena and objects.*
	6	*How the ship floating (Buoyancy, gravity) Why do we have the blue sky (refraction of light, spectroscopy, optics of science), why does the rainbow have seven colors (spectral, refraction)* *In order to solve the questions, I come up many ideas in my mind, I can tell the process of taking out various ideas and structuring them.* *It is the **process of drawing out various thoughts about one question**, searching for the answer, and finding the answer through the link between the answers.* ***Students can have different thoughts about each question**, but it is difficult to ask specific questions about the question for the solution. Students cannot find any link between the questions.* *Scientific thinking is the ability to **derive a variety of ideas to solve the answers** to emerging questions and to deduce results based on scientific evidence.*
		….. [*Omitted*]….

scientific thinking as follows in Table 3. Those responses were some parts out of 10 different responses.

For rational component of scientific thinking, science is the process to find out the relationship between cause and effect; *finding factors affecting the phenomenon* (respondent 1), *conceives a sequence of probable factors that may cause* (respondent 3) and *identifying the evidence* (respondent 4). For example, respondent 1 provided the episode of students' activity where students try to find out what factors influence that roller coaster runs completely. Students can explain how this roller coaster runs completely with factors they round. Respondent 1 assumed that science thinking comes from finding out reasons/factors influencing the phenomenon. For another component of logical thinking, responses included as follows; *logical and systematic thinking, finding patterns and induction, logically explain their claims, why question,* and *express their ideas* with concrete episodes. For critical thinking component, responses were analyzed as follows; *students express their ideas differently, they* *can have different ideas about the question,* and *they also derive various ideas for solution.* In addition, creative thinking is also suggested as one of important scientific thinking on the basis of researchers' experience in science teaching and learning and a few responses of 'new' or 'different' terms in their survey. Therefore, from empirical data by open questionnaire, 4 thinking skills are recognized as scientific thinking, which are rational, logical, critical, and creative thinking from the empirical data.

Next, 4 components of scientific thinking derived from 10 participants' responses were compared with those from theoretical literature where scientific thinking is introduced or defined by other authors. Literature research has been searched by using the keyword of 'scientific thinking' at google and the researchers selected a few most cited literatures or well-known literature for comparison. Scientific thinking was defined to be classified into three; logical, critical, and creative thinking. Logical one is divided into two; deductive and inductive thinking (Kim, 2013; Cho, 2009). 'Rational' thinking was found to be overlapped with other two thinking; logical and critical one. Therefore, the researchers decided to exclude 'rational' one in the 2nd process after comparing with theories. This is how the researchers constructed the validity for each competency with component and practical indicators in frame. In the same way, each competency is defined by 3 or 4 components with practical indicators each.

Finally, the survey of Likert scale was employed to another 35 science educators (teachers at schools or interpreter at museums) to construct another content validity. The following is one of example survey with personal opinions left in the right side (Table 4). In this case, there was no more additional opinion in

Table 4. The sample of one respondent in survy of Likert scale for core competency

Science core competency	Component	√	Opinion
Scientific Thinking	Logical Thinking Critical Thinking Creative Thinking	√ √ √	
Scientific Inquiry ability	Recognizing Scientific Problems Collect data with various exploration Analyzing collected data To interpret the results and draw a conclusion	√ √ √ √	*I would like to mention the hypothesis.* *It is also mentioned in the first section of science, high school life science 1 in junior high school.* *In middle school, it is important to mention the setting of hypotheses during the scientific inquiry process.* *On the left side, there are only about half of the basic inquiry process and the integrated inquiry process.* *In order to develop the core competence of scientific inquiry, it is necessary to write contents to dissolve other unexplored inquiry processes.*
Scientific problem-solving ability	Recognizing the Scientific Issues in Daily life Identifying the scientific factors relating to the problem Reflective thinking To present and implement a solution	 √ √ √	*'Recognition' is considered to be a factor in the 'scientific inquiry ability' core competency.* *Of course, recognizing the problem is the first thing to solve the problem, but it overlaps with the core competence of scientific inquiry.* *Duplication of details in multiple core competencies can be a bit ambiguous and ambiguous about core competencies must be limited.*
Scientific communication ability	Communicate in various ways Demonstrating Coordinate opinions Know how to use various media	√ √ √ √	*If you know how to use it, you will not develop communication skills.* *Beyond usage, you need to present your plans together to cultivate your communication skills.*
Scientific engagement and lifelong learning ability	Recognizing community problem Interested in SSI or STS Issues Learning voluntarily Understanding the Science Daily life	√ √ √	*The fact that voluntary learning is so comprehensive is not clear.*

scientific thinking component, which indicated that the respondents agreed to have three components of scientific inquiry competency without any addition or change. But other competencies had some opinions left by the respondents so the researchers used those opinions to modify or add some more description in practical indicators.

About the survey of Likert scale, there has been agreement among respondents of 35 as follows; *logical thinking* (94%, 33/35), *critical thinking* (91%, 32/35), and *creative thinking* (91%, 32/35). If there was any opinion, the researchers discussed them and decided to add some in practical indicators or modify them to be included finally to the frame.

Scientific inquiry competency: Responses from participants were characterized as follows; (1) abilities to predict the results through inferring and thinking process by comparing two experimentations, (2) abilities to recognize the question, design the investigation, collect the data and analyze them to be presented by computer for the results, (3) abilities to withdraw the meaningful results through experimental processes, abilities to reorganize the prior knowledge by processing them, (4) abilities to do experimentation with scientific thinking, (5) abilities to do discovery learning through reflective thinking by trial and error, and (6) abilities to do basic skills like observation, measurement, and classification with the use of frame. One of example in these skills of scientific inquiry is as follows.

> *In* ***exploring the relationship*** *of intensity of light along a distance, it is recognized that the intensity of light decreases according to the distance, but it must be recognized as to how much it decreases. To solve this, the* ***light source changes*** *the intensity of light and* ***quantify the relationship*** *of light intensity along the distance through a large amount of* ***objective data*** *obtained through various* ***methods*** *such as minimizing the influence of ambient light* (example from respondent 3 about physics content).

Respondent 3 talked about the episode of what relationship students could find by exploring the experimentation with different variable. First, it is first to do to discern variable into independent, dependent, and control variables. Then exploration the relationship by experimentation is the second. The temporary components of scientific inquiry derived from this empirical data were compared with theories (Jeong, 2011; Choi & Kang, 2002). Scientific inquiry described in science curriculum of 2007 consists of integrated inquiry skill as well as basic one. The basic inquiry skill consists of observation, classification, measurement, inference, and prediction, whereas, integrated one consists of framing question, making hypothesis, controlling variables, interpreting the data, and concluding remarks. Most of components from empirical data were validated with theoretical data.

About the survey of Likert scale, there has been agreement among respondents of 35 as follows; *recognizing scientific problems* (88%, 31/35), *collect data with various exploration* (85%, 30/35), *analyzing collected data* (88%, 31/35), and *to interpret the results and draw a conclusion* (94%, 33/35). If there was any opinion, the researchers discussed them and decided to be added or not to the frame also. For example, there was opinion to include *making hypotheses* into one of components and the researchers decided to combine it with *recognizing scientific problems* to be finally *make hypothesis and design* at the end.

Scientific Problem solving competency: Responses about problem solving competency were described as follows; (1) abilities to find the solution by applying scientific knowledge and thinking by the unit of individual or society, (2) abilities to find out more influential factors in the reality, (3) abilities to explore more effective ways to find out the solution, (4) abilities to make decision reasonably, to reflect on, and to be patient to find out the solution, (5) abilities to stand own position and defend mine for SSI (social scientific issue), and (6) abilities to consider ethics to the final scientific product. This is totally different from scientific inquiry. Responses indicated that problem solving is more related to applying scientific concepts/knowledge in daily life rather than scientific inquiry more related to forming/understanding scientific concepts (Park, 2018).

> ***To identify the causes*** *of traffic accidents, we* ***obtain various evidences*** *from accident site. First, where two cars are located, how much those cars are damaged, where the skid mark is, how the road condition of the accident scene is, how much the driver 's condition are secured and so on. Each piece of evidence tells us the cause of the accident. This is an example of application of scientific problem solving* ***ability in everyday life*** (example of Respondent 8 about how to apply knowledge for car accident).

Respondents 8 illustrated that problem solving skill is the process of redefining the problem to the solution in the reality step by step like puzzle so she thought that prior scientific knowledge is applied to find the answer. Then, the temporary components derived from these responses of problem solving competency were compared to those from theoretical review; *reframing and confirming the problem, proposing possible strategy for solution* (this is like making hypothesis in scientific inquiry), *collecting information and selecting the best for solution, and suggesting the solution and elaborating it* (Choi, 2008; Cho et al., 2000).

About the survey of Likert scale, there has been agreement among respondents of 35 as follows; *recognizing the scientific issues in daily life* (80%, 28/35*), identifying the scientific factors relating to the problem* (88%, 31/35), *reflective thinking* (77%, 27/35), and *to interpret the results and to present and implement a solution* (85%, 30/35). If there was any opinion, the researchers discussed them and decided to be added or not to the frame also. About reflective thinking, people suggest possible solution by checking its appliance to the daily life from the views of economics, society, and politics and so on. Therefore, suggesting the possible solution through reflective thinking is very appropriate for the frame.

Scientific communication competency: Responses from 10 participating about scientific communication were analyzed to have the following characteristics; (1) abilities to discuss to find out the best conditions for the solution with the use of scientific terms, (2) abilities to make people understood easily, (3) abilities to make my claim logic to be understandable by others and deliver my intention by various type of media, (4) abilities to assist other people’s stance or debate different position, (5) abilities to use different media according to different goal of communication, (6) abilities to understand the audience and prepare appropriate talk, (7) abilities to understand other position and present my position by own language, (8) abilities to share the ideas and accept other position, and (9) abilities to represent own ideas by graphs or drawing.

> *Science communication is the ability to* ***share and critically accept*** *scientific action or outcome with others and it includes the ability* ***to express one's thoughts*** *to others and the ability to* ***accept others' opinions*** *also. I can say also that science communication includes understanding and dealing with the characteristics of basic communication styles (symbols, terms, etc.) and media (ICT, etc.) used in science* (example about science communication from respondent 9)

Respondent 9 described that science communication is the way of interacting with people rather than the content to be communicated. Park (2018) released that scientific inquiry is what must be delivered through science communication which is defined as the ‘way’ of interacting. These temporary components were compared to those from theoretical review; *share the ideas through different type of interacting, develop the argumentation, adjust own ideas to others,* and *recognize the best way to represent own ideas* (Cheon, 2013; Kim, 2017; Park, 2018).

About the survey of Likert scale, there has been agreement among respondents of 35 as follows;

communicate in various ways (94%, 33/35), *demonstrating* (88%, 31/35), *coordinate opinions* (77%, 27/35), and *know how to use various media* (60%, 21/35). If there was any opinion, the researchers discussed them and decided to be added or not to the frame also. About 'know how to use various media', the researchers summarized that people need to use various type of representation appropriate to the purpose of communicating rather than types of technology on the basis of left opinions by respondents.

Scientific engagement and lifelong learning: Responses about scientific engagement and lifelong learning were characterized as follows; (1) develop enough information about the community for reasonable decision, (2) recognize own role to the society, (3) collaborate with others for the positive impact to the society continuously, (4) participate in making decision with responsibility for the society, (5) show willingness and behaviors for the engagement in learning new knowledge in the community, (6) recognize the necessity of re-education due to a change society, (7) perceive the necessity of lifelong learning, (8) engage in learning science and technology changing newly and rapidly in society, (9) extend and apply scientific knowledge in daily life, and (10) keep concerned about SSI to solve the problem with responsibility as lifelong learning.

> *Scientific engagement and lifelong learning ability can be said to learn scientific education* ***regardless of age****, to know the change of science and technology development, and to* ***continuously learn new changing and evolving science and technology****, industry and social life skills. It is so related to solve the curiosity intellectually about scientific literacy and advanced science and technology and to promote understanding of science knowledge* ***in daily life****. Lifelong education is a way of lifelong learning. Lifelong learning can be done at various times and places* ***no matter how old you are****. Currently science museum also has a "****Senior Science Academy****" for understanding science and technology in current society and "****Academy for parents****" for their engagement in science learning with their own kids for their professional career* (example from respondents 6 about science engagement and lifelong learning).

Respondent 6 described scientific engagement and lifelong learning as willingness and behaviors of showing continuous interest in learning science and technology changing rapidly in the community. The temporary components of scientific engagement and lifelong learning were compared to those of literature review; abilities in language skill in representation and comprehension, abilities of social skills (self-confident, self-directed, self-management), abilities of learning about how to learn, abilities to cope with change and adaption, and resilience to changing information (Park, 2013). Lifelong learning is defined also as a broad concept as education that is flexible, diverse and available at different times and places through the life (Laal, 2011). People in society have the right to have support from the community for lifelong learning which encompasses all activities of an educational nature with an ultimate goal of universalization of self-education. Its objectives involve successful adjustment to life; all-round development of the person; and establishment of an equitable society.

About the survey of Likert scale, there has been agreement among respondents of 35 as follows; *recognizing community problem* (85%, 30/35), *interested in SSI or STS Issues* (88%, 31/35), *learning voluntarily* (62%, 23/35), and *understanding the science daily life* (85%, 30/35). If there was any opinion, the researchers discussed them and decided to be added or not to the frame also. For the case of *learning voluntarily,* scientific engagement includes people's self-directed learning with the motivation, therefore, the researchers summarized that *self-directed participation/ engagement* is appropriate.

Completing the Science Core Competency Analyzing Frame

From the analysis and interpretation of data, 19

Table 5. Science Core Competency Analyzing Frame

Competency	Component	Indicator
Scientific thinking	Logical Thinking	analyze and explain the phenomena with evidences
	Critical thinking	evaluate the phenomenon with argumentation
	Creative thinking	represent the ideas through various ways
scientific inquiry	Make hypothesis and Design	make hypothesis and design it about SSI
	Collect the data	collect the data through inquiry skills like observation, prediction, inference etc.
	Analyze and Interpret the data	analyze and interpret the factors from data and its relationship
	Conclude and Generalize	make conclusion and generalize commonality and patterns from analyzed the data
scientific problem solving	Identify problems from daily life	identify the problem from daily life and interpret it by science
	Selecting the information and Evaluate it	select and evaluate the most appropriate data for solution
	Suggest the possible solution	propose the possible solution for problem
	Explore its implementation	select the practical ways for solving the problem
scientific communication	Use various type of communication	represent the ideas through various types of ways, verbal or writing one, and drawing
	Make argumentation with evidences	prove scientifically about right or wrong of the situated problem
	Adjust with other opinions	adjust opinions through argumentation
	Understand the information through media	learn and understand information by various media like computer and visual materials
Scientific engagement and lifelong learning	Identify the problem in the community	understand the problems in the unit of community
	Communicate about SSI	suggest my idea for SSI
	Self-directed participation	keep participating in science activity self-directly
	Learn and Apply new science technology	learn and apply new science technology

components were developed with practical indicators in 5 science core competency (Table 5). Scientific thinking consists of logical, critical, and creative ones (3 components) while students do scientific inquiry activities. Scientific inquiry is the process of making hypothesis, collecting the data, analyzing and interpreting the data, and concluding and generalizing the results (4 components). Scientific problem solving is the ability of recognizing the problem and selecting the best solution from evaluation (4 components). Scientific communication is the ability to represent opinions through different types of communication in science through argumentation, adjustment, and understandings from different media (4 components). Finally scientific participation through life-long education is ability to find out the problem from daily lives such as social scientific issues (SSI) and learn new science and technology through self-directed participation (4 components). These all competencies are critical ones for students to be creative problem solvers expected in science education of Korea.

Applying Science Core Competency Analyzing Frame into STEAM program

The researchers used science core competency analyzing frame (SciCoCoAF) in two STEAM programs to see what components of science core competency could be found and how much. The STEAM programs used in this study have been developed earlier than this frame development by the researchers but the reason why the researchers checked this frame's application was to see if STEAM programs included those competencies. The purpose of STEAM education are to produce the creative problem solvers equipped with those science core competencies. Even though the STEAM programs have been developed earlier rather than their introduction of science core competencies in the 2015 revised science curriculum, the pursuing goal of these two science education policies, producing creative problem solvers, is same; therefore, it is meaningful to check if science core competencies are included in STEAM program. This process is also how to construct the validity of

Table 6. Climate Change STEAM program for high school level used in this study

stage	#	Topic	
Present situation	1	What is plastic from CO_2?	Students first are motivated to solve the problem of climate change in the community and they also learn basic concepts of climate change.
	2	How does climate change?	
	3	Does climate change in our city? How can we know?	
Creative design	4	What is greenhouse effect?	Students design various types of experimentation to learn more about scientific concepts of climate change and suggest the possible solution to consume CO_2 by activating photo bioreactor in the community.
	5	Why does greenhouse effect happen?	
	6	Is CO_2 greenhouse gas?	
	7	What characteristics of greenhouse gases are?	
	8	What are microalgae?	
	9	Making Carbon dioxide reduction device	
Emotional experience	10	How to reduce CO_2?	Students designed the photo bioreactor for alternative energy resource.

Table 7. Water Shortage STEAM program for high school level used in this study

	#	Topic	
Present situation	1	Find out possible water resources	Students recognize that there are limited water resources in the community and they waste water at home and in the community.
	2	Deliver water where you need it	
	3	How to remove used water and rainfall	
Creative design	4	Construct water purification equipment	Students learn what system of water exist to save water and store water internationally. Students suppose possible solution for saving water in the community by developing water purification equipment.
	5	How effective is my equipment?	
	6	Develop water storage equipment	
	7	From water storage to water management	
Emotional experience	8	Develop water management system in my city	Students design the city/community with effective system and represent it by drawings.
	9	Contest of city water management system	
	10	City water management, I can do it.	

SciCoCoAF.

Two different STEAM programs at middle school levels designed by the researcher group in 2012 were selected in this study. One theme is climate change and the other one water shortage. Students are motivated to solve the climate change problem in the community (Table 6).

In climate change STEAM program Table 6, students at middle school are expected to learn basic scientific concepts and apply those concepts to understand the function of Carbon dioxide reduction device. They also use App to know how much they personally produce CO_2. Students use tools ready for photo bioreactor to consume CO_2 by green algae and produce oil at the end by drying them. The photo bioreactor is one designed engineering and technologically but students follow the steps to produce the same equipment.

Next one is water shortage STEAM program analyzed by SciCoCOAF to check its validity. The content what students learn is introduced below (Table 7).

Table 7 shows the topics of water shortage STEAM program where students learn scientific concepts about water function and water system and understand the function of water purification and storage.

The below is one example of how the researchers analyzed the lesson plans of 10 in each STEAM topic to see what kinds of science core competency were and how much they were included (Table 8). The researchers analyzed general description about this lesson, their learning objectives given in ①, then coded them with indicators from SciCoCoAF in ②. The researchers also provided the evidences form the lesson (③) matching to each competency analyzed in ②.

Here, there had been two competencies dominating in this lesson; *scientific communication and scientific*

Table 8. The example of anlayzing lesson plan in 1st block of climate change STEAM program

	the 1st lesson What is carbon dioxide plastic?
①	- understand why understanding the process of producing carbon dioxide plastics is an important issue for our economy. ※Be aware of the significance of properly responding to climate change
②	Scientific communication ability_ **Demonstration based on Scientific evidence** Scientific communication ability_**Accepting other's opinion and coordinating** Scientific engagement and lifelong learning ability_**Talking about social issue** Scientific engagement and lifelong learning ability_**Attending self-directed and consistently**
③	**Demonstration based on Scientific evidence:** In groups, we can talk about the importance of plastics made from carbon dioxide and how carbon dioxide can be reduced on the basis of evidences scientifically **Accepting other's opinion and coordinating:** During discussion, students accept others' opinion and make a decision on why plastics made from are important and how carbon dioxide can be reduced **Talking about social issue:** Know that global warming is causing serious damage to humans, and we can talk about ways to reduce the carbon dioxide that causes global warming**.** **Engaging self-directly and consistently:** Self-indulgence and continuous participation can be possible by asking more questions to find out the solution in or out of the classroom or in the community.

engagement and lifelong learning. Students have chances to provide evidences of how plastics from carbon dioxide can be made and what it means in climate change. Students become to recognize how climate change is serious issue to be considered in person or in the community. Students learn how to be logic in talking about science with stance and how to adjust own ideas to others by accepting or rejecting in mannered. Students started to feel they belong to the community and feel responsibility to solve the problem in the community.

When the researchers applied science core competency analyzing frame into this program, the trend of science core competency in climate change was as follows; science communication competency was most dominating competency, where students communicate and present their own ideas while they learn new concepts and apply them. Scientific problem solving was the least used competency since students did not suggest various types of solutions. Students proposed only photo bioreactor for consuming CO_2 and producing oil as the solution of climate change. However, students had chance to evaluate this equipment in its efficiency. In scientific thinking, logical thinking component was used most. In scientific inquiry, analyzing and interpreting the data was used most. In scientific problem solving, proposing the possible solution for problem was not found at all, since students followed the steps of making equipment. In science communication, making argumentation and adjusting them was balanced in their use. In scientific engagement and lifelong learning, each component was found in some degree Fig. 2.

In case of water shortage STEAM program, 5 science core competencies were generally balanced in their frequencies in water shortage STEAM programs (Fig. 3) when compared to those of climate change one (Fig. 2). Students used scientific thinking and scientific inquiry competency when they learned new concepts about water shortage. Students became to know the problem from the community due to water storage and deliver system and to think system creatively to save and purify water for planning city. This all process came out through scientific problems solving competency. Students became to feel responsibility as one of member in the community to save water for the community. It can be said that every competency was used in this STEAM program.

In general, it is summarized that the application of science core competency analyzing frame was possible and each component with indicators was mesurable and observable. This is how the researchers constructed the validity and reliability of this frame.

Conclusions and Implication

First, science core competency analyzing frame was found to be useful with sub components and practical

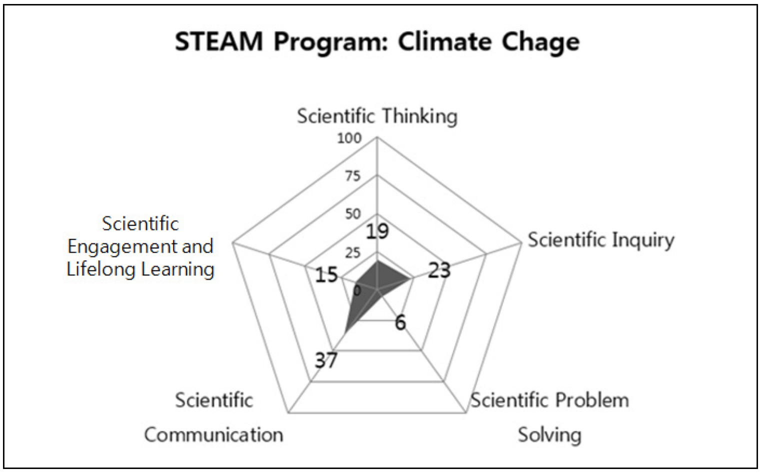

Fig. 2. The science core competency included in climate change STEAM program.

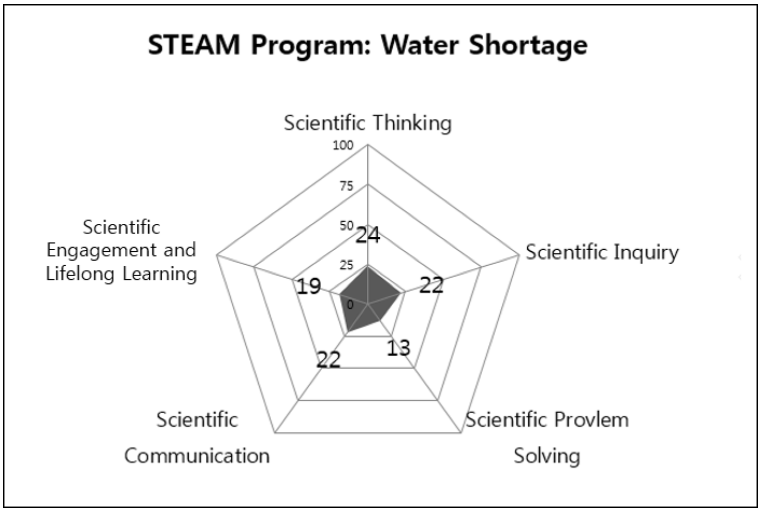

Fig. 3. The science core competency included water shortage STEAM program.

indicators each. Each competency consists of 3-4 components and there are 19 components for 5 science core competency. So, this would be meaningful for science teachers to understand what science core competencies are and how they can be described with practical indicators observable in science program or science teaching. Each component in each competency is disguisable each other and each indicator is described explicitly to be measurable. The components between scientific inquiry and scientific problem solving competencies can be distinguished in terms of the purpose of implementing those competencies. That is, scientific inquiry competency can be found when students form science concepts and scientific problem solving competency can be found when students apply science concepts during program. Even though there are similar steps of collecting data in scientific inquiry competency and selecting information in scientific problem solving competency, the former data come from scientific experimentation and the latter one from investigation or experimentation of technology and engineering. For example, students in climate change STEAM program experimented to find out which gas is most influential one for greenhouse effect, which is the process of scientific inquiry when forming concepts. However, when students investigate what shape of mirror (square, hexagon, or round shape) is the most effective for photosynthesis by reflecting the light, this is the process of scientific problem solving where students collect the information to be selected and evaluated as the best solution. Scientific communication can show with scientific thinking competency in that students can represent their ideas with exact evidences and students experience logical thinking at the same time. Overall, scientific inquiry comes first and scientific problem solving competency comes after with the surroundings of the other three competencies in the context of STEAM program.

Second, this frame can be useful in prescribe what competency are included or not so that we can make up the missing/limited competency for better program in a sense of meeting the goal of science education, producing creative problem solvers. In climate change, the usage of scientific problem solving competency was low when compared to other competencies since students did not provide different types of solution, but same one installation. Therefore, for better program for students to experience all components from 5 competencies, it is necessary to improve scientific problem solving competency by providing chances for students to create their own photo bioreactor different from each other group. It is confident that this frame is very useful to check what kinds of competency are and how many those competencies are different in their frequency. Now, it is necessary to make each competency scored in levels with descriptive rubrics in the future study. For example, one component of scientific problem solving includes 'suggest the possible solution'. If students just suggest the solution but which is not possible, then the score will be 'low'. If students suggest the solution which is possible after checking its usage in the community from the view of economics, then the score can be 'middle'. Finally, if students suggest the possible solution after checking the usage from a few different views, then the score will be 'high'. Therefore, it is very essential to modify and rebuild this analyzing frame with concrete rubrics in each component so that teachers and other educators can understand and use them as planning and assessing tools for science core competency for STEAM program.

Finally, one implication can be made in teacher education for teachers' expertise in their profession in teaching and learning science. This frame must be developed as guideline with concrete examples in each indicator of each component in each competency. It is implied that revised science curriculum must be provided with concrete guidelines so that teachers could learn and apply them easily into the classroom in and out.

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References

Choi K., Lee H., Shin N., Kim S., and Krajcik J., 2011, Re-conceptualization of scientific literacy in South Korea for the 21*st* century. Journal of Research in Science Teaching, 48(6), 670-697.

Cho, H-H., Kim, H-K., Yoon, H., and Lee, K., 2009, Theory and Practice of Science Education. Kyoyoobook.

Choi, S-Y. and Kang, H., 2002, The comparative analysis of science process skills and teaching methods in the 6th and the 7th elementary school science, 22(4), 706-716.

Choi, S-Y. and Seo, J-H., 2008, The effects of using digital textbooks on science and problem solving ability. Korea Educational Research and Information Service

Cho, Y-D. and Yoon, Y-S., 2014, Curriculum of mathematics in Korea and Japan compared with the perspective of fostering core competencies. Journal of Mathematics Education, 24(1), 45-65.

Cho, Y-S., Sung, J., Chae, J-S., and Gu, S., 2000, Development and application of elementary science curriculum for creative problem solving. Journal of the Korean Association for Science Education, 20(2), 307-

328.
Crawford, B., 2000, Embracing the essence of inquiry: New roles for science teachers. Journal of Researh in Science Teaching, 37(9), 916-937.
Gormally. C., Brickman, P., Hallar, B., and Armstrong, N., 2009, Effects of inquiry-based learning on students' science literacy skills and confidence. International Journal for the Scholarship of Teaching and Learning, 3(2), 1-24.
Jeon, S-S., 2013, Development of scientific communication Skill test for elementary school students. Korea National University of Education Graduate School of Education Ph.D. Thesis
Jung, M-N., 2011, The analysis on the sources of science self-efficacy of middle school science-gifted students. Ewha Womans University Graduate School of Education Master's Thesis
Kwak, Y., 2016, Science and competency centered curriculum. Kyoyoobook.
Kim, J., 2017, What is science commuication and why do we need to do this? The Science ON website. http://scienceon.hani.co.kr/
Kim, H-B., 2015, The effect of experimental lessons enhanced discussion activities on elementary students' scientific communication ability. Gyungin University of Educatioin Graduate School of Education Master's Thesis.
Kim, H-Y., 2013, Analysis of the science writing in middles school science textbook for the revised 2009 science educational curriculum. Ewha Womans University Science of Education Master's Thesis
Lee, C-S., 2015, The core competency of the 2015 revision curriculum, there is a serious problem ! Educational Research & Innovation Center of Korea.
Lee, O., 1997, Scientific literacy for all: What is it, and how can we achieve it? Journal of Research in Science Teaching, 34(3), 219-222.
Ministry of Education, Science and Technology, 2006, Commentary on middle school curriculum (3). Seoul: Ministry of Education & Human Resources Development Notice
Ministry of Education, 2015, Science Curriculum. Ministry of Education Notice 74
NRC, 2000, Inquiry and the national science education standards. Washington, D.C. National Academy press.
OECD, 2006, Schooling for tomorrow: Think scenarios, rethink education. OECD: Paris.
Park, G., 2014, Exploratory empirical study on life long learning practices of lifelong learners. Dong Eui University Graduate School of Education Master's Thesis.
Park, Y-S., 2006, Theoretical study on the opportunity of scientific argumentation for implementing authentic scientific inquiry. Journal of Korean Earth Science Society, 27(4), 401-415.
Park Y-S., 2010, Secondary beginning teachers' views of scientific inquiry: with the view of hands-on, minds-on, and hearts-on. Journal of Earth Science Society, 31(7), 798-812.
Park, Y-S. and Hwang, J-K., 2017, The preliminary study of developing computational thinking practice analysis tool and its implication. Journal of Korean Sciety of Earth Science Education, 10(2), 140-160.
Park, Y-S., 2018, Science Museum Guideline. National Science Center.
Park, Y-S. and Park, M., 2018, The study of development elementary science program with the computational thinking and teaches' percetion. The 1st Korea geoscience union conference, Gangwon-do, Hongcheon, Daemyeong Vivaldi Park, May 5th to 9th.
Park, J-J., Yun, J-H., and Kang, S-J., 2014, Development and validation of a scientist's core competency model for competency-centered science gifted education. Gifted Education Research, 24(4), 509-541.
PISA, 2006, OECD Programme for International Student Assessment.
Rychen D. and Salganik L., 2003, Key competencies for a successful life and well-functioning society. Hogrefe and Huber. Cambridge, 41-62.
Sanders M., 2009, STEM, STEM education, STEMmania. The Technology Teacher, 68(4), 20-26.
Schwarz, C. V., Reiser, B. J., Davis, E. A., Kenyon, L., Acher, A., Fortus, D., Sharwtz, Y., Hug, B., and Krajcik, J., 2009, Devloping a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. Journal of Research in Science Teaching, 46(6), 632-654.
So, K-H., 2007, "Competence" in the context of schooling: it's meaning and curricular implications. The Journal of Curriculum Studies, 25 (3), 1-21.
So, K-H., 2009, Curricular-historical base and its liberal nature of competence-based education. The Journal of Curriculum Studies, 27(1), 1-20.

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